Bacteria TMDL for Birch Creek Watershed, Virginia

Submitted by

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Executive Summary

This report presents the development of a Bacteria TMDL for the Birch Creek watershed. Birch Creek is a tributary of the Lower Dan River Basin. The Birch Creek watershed is approximately 40,620 acres, or 63.5 square miles. The watershed is located within Pittsylvania and Halifax counties in Virginia. Approximately 41.5 percent of the drainage basin is located in Pittsylvania County; the remainder of the watershed is located in Halifax County. The Birch Creek watershed makes up about 2.7 percent of the land area in Pittsylvania County, and 4.5 percent of the land area in Halifax County. State Highway 360 (SH-360) runs through the northern boundary of the watershed in an east to west direction. The Birch Creek impaired segment is 4.83 miles in length. The segment begins at the confluence of Birch Creek and Carlton Creek, and ends at the mouth of Birch Creek at the Dan River.

Birch Creek was listed as impaired on Virginia's 2002 303(d) Report on Impaired Waters (DEQ, 2002) because of violations of the bacteria water quality standard. At the time of the Birch Creek listing the Virginia bacteria water quality standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in E. coli. Virginia's bacteria water quality standard currently states that E. coli bacteria shall not exceed a geometric mean of 126 E. coli counts per 100 ml of water for two or more samples over a 30-day period or an E. coli concentration of 235 counts per 100 ml of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in E. coli by converting modeled daily fecal coliform concentrations to daily E. coli concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous E. coli water quality standard.

The TMDL development process must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that

TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect bacteria loading.

Land use characterization was based on National Land Cover Data (NLCD), developed by USGS. Dominant land uses in the watershed are forested land (71%) and hay/pastureland (19%), which account for a combined 90% of the land area in the Birch Creek watershed.

Birch Creek flows through a predominantly rural setting, with very little urban land present in the watershed. Runoff from livestock grazing, manure applications, industrial processes, residential waste, and failed septic systems can contribute to increased levels of bacteria in the surface waters. Sources may be driven by dry weather or wet weather. The potential sources of fecal coliform in the watershed were identified and characterized. These sources include failed septic systems and straight pipes, livestock, wildlife, and pets.

An inventory of the livestock residing in the Birch Creek watershed was conducted using data and information provided from the DCR, Halifax and Pittsylvania Soil and Water Conservation Districts, NRCS, and field surveys. The data and information indicate the following:

- beef cattle operations exist on pasture areas throughout the watershed
- no feedlots are located in the watershed
- no dairy operations exist in the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the stream
- other livestock are present in the watershed

Bacterial source tracking was conducted at three stations on Birch Creek; one station (4-ABIR001.00) was located at the intersection of the creek with the Route 659 Bridge, another (4-ABIR005.34) at the intersection of the creek with Route 662, Birch Elmo road, and the third (4-AXDK000.94) at the intersection of an unnamed tributary of Birch Creek and Route 683. Samples were collected and analyzed monthly from December 2002 through November 2003, for a total of 12 sampling events at each station. The data indicate that E. coli from human, wildlife, livestock, and pet sources were present in Birch Creek. The human signature ranged from 0 to 100 percent, the wildlife signature ranged from 0 to 79 percent, the livestock signature ranged from 0 to 100 percent, and the pet signature ranged from 0 to 59 percent.

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of Birch Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Birch Creek model were used to develop the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

The Birch Creek watershed was delineated into 20 smaller subwatersheds to represent watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital

Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Since stream flow monitoring data were not available in the Birch Creek watershed, the paired watershed approach was used in the set-up and calibration of the HSPF model. The basis of this approach is to develop the model for a hydrologically similar watershed where data are available, then to transfer the calibrated model to the watershed with the insufficient data. Criteria used to evaluate similarities in the hydrologic characteristics of these watersheds included watershed physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use/land cover) and mean annual precipitation.

Five streams with sufficient hydrologic data were identified for potential use as the paired watershed to Birch Creek. These included Totopotomoy Creek (USGS1673550), Fine Creek (USGS2036500), North Meherrin River (USGS2051000), Allen Creek (USGS2079640) and Falling River (USGS2064000). It was determined that Falling River would be used in this paired watershed approach.

Weather data for the Lynchburg, VA WSO Airport and the John H. Kerr dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Lynchburg airport recorded data from 1952 to 2001, and the John H. Kerr dam recorded data from 1948 to the present. For this TMDL, the recorded data at Lynchburg and the Kerr dam were combined based on their proximity to the Falling River watershed, which was used as the paired watershed to Birch Creek. The combined rainfall record consisted of 75 percent Lynchburg weather data and 25 percent of the weather data obtained from the John H. Kerr dam.

HSPEXP software was used to calibrate the hydrologic model for Falling River, which was the paired watershed to Birch Creek. Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Falling River model was calibrated for January 1997 to December 1998. The period of January 1996 to December 1996 was used to validate the HSPF model. The validation results are presented in this report. The expert system calculates certain statistics; compares the model results with observed flow values; and provides guidance on parameter adjustment. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the Falling River watershed. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Station 4-ABIR001.00 has water quality data from 1993 to 2001 representing a total of 39 sampling events. Water quality data for station 4-ABIR001.00 was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period of January 1995 to December 1996 was used for water quality calibration of the model, and the time period of January 1998 to December 2000 was used for model validation.

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2000. Virginia has recently changed its bacteria standard from fecal coliform to E. coli; therefore modeled fecal coliform concentrations were changed to E. coli concentrations using a translator. Water quality standards for both fecal coliform and E. coli were exceeded for the most part during this time period.

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean E. coli standard of 126 cfu/100 ml and the instantaneous E. coli standard of 235 cfu/100 ml with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1995 to December 2000, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of the Birch Creek watershed. Because Virginia has recently changed its bacteria standard from fecal coliform to E. coli, modeled fecal coliform concentrations were translated to E. coli concentrations, and the TMDL allocation plan was developed to meet geometric mean and instantaneous E. coli standards. Based on the load allocation scenario analysis, the TMDL allocation plan that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous E. coli water quality standard of 235 cfu/100ml requires:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 69 percent reduction of the direct instream loading from wildlife.

A summary of the bacteria TMDL allocation plan loads for Birch Creek is presented in Table E-1.

Table E-1: Birch Creek TMDL Allocation Plan Loads for E. coli (cfu/year)

Point Source (WLA)	Non-point Sources (LA)	Margin of Safety (MOS)	TMDL
0	6.04E+12	Implicit	6.04E+12

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

The development of the Birch Creek TMDL would not have been possible without public participation. The first public meeting was held in the Town of Halifax on October 23, 2003. Nine people attended the meeting. The following information was presented:

- listed segment of Birch Creek,
- the data that caused the segment to be on the 303(d) list,
- review the TMDL process;
- the livestock, wildlife, and pet inventories;
- the fecal coliform sources assessment
- the calculation used to estimate the total available fecal coliform load;
- explanation of the assumptions used in the calculations; and presentation of the HSPF model.

The second public meeting was held in the Town of Halifax on February 23, 2004 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Ten people attended the meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations*.

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1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency (EPA)'s Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to better develop and regulate a more effective TMDL process. The role of DEQ is to act as a lead agency for the development of statewide TMDLs. DEQ focuses its efforts on all aspects of pollution reduction and prevention to the state waters. DEQ ensures compliance with the Clean Water Act and the Water Quality Planning Act, as well as encourages public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs on a statewide level through the use of grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits from industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001a).

The Clean Water Act requires every state to develop a list, referred to as the 303(d) list, of impaired waters that details the pollutant(s) in violation and the potential source(s) of each pollutant. The Water Quality Monitoring Information and Restoration Act was passed in 1997 by the Virginia General Assembly to guide DEQ in creating and implementing TMDLs for the state waters on the 303(d) list (DEQ, 2001a). Virginia's 2002 303(d) report lists Birch Creek (ID# VAC-L63R-01) as impaired for fecal coliform.

As required by the Clean Water Act and the Water Quality Planning and Management Regulations, once the TMDL has been developed, it should be distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Birch Creek was listed as impaired on Virginia's 2002 303(d) Report on Impaired Waters (DEQ, 2002) because of violations of the state's water quality standard for fecal coliform. Water quality monitoring samples from station 4-ABIR001.00, located at the Route 659 bridge, failed to attain the primary contact designated use in 7 out of 26 samples.

Birch Creek is located in the Lower Dan River Basin in southern Virginia (Figure 1-1). Birch Creek runs through Pittsylvania and Halifax counties, and is a tributary of the Dan River. Birch Creek is located in hydrologic unit (HUC) 03010104.

The Birch Creek impaired segment is 4.83 miles in length. The segment begins at the confluence of Birch Creek and Carlton Creek, and ends at the mouth of Birch Creek at the Dan River. Figure 1-2 is a map showing the Birch Creek listed segment.

Figure 1-1: Location of the Birch Creek Watershed

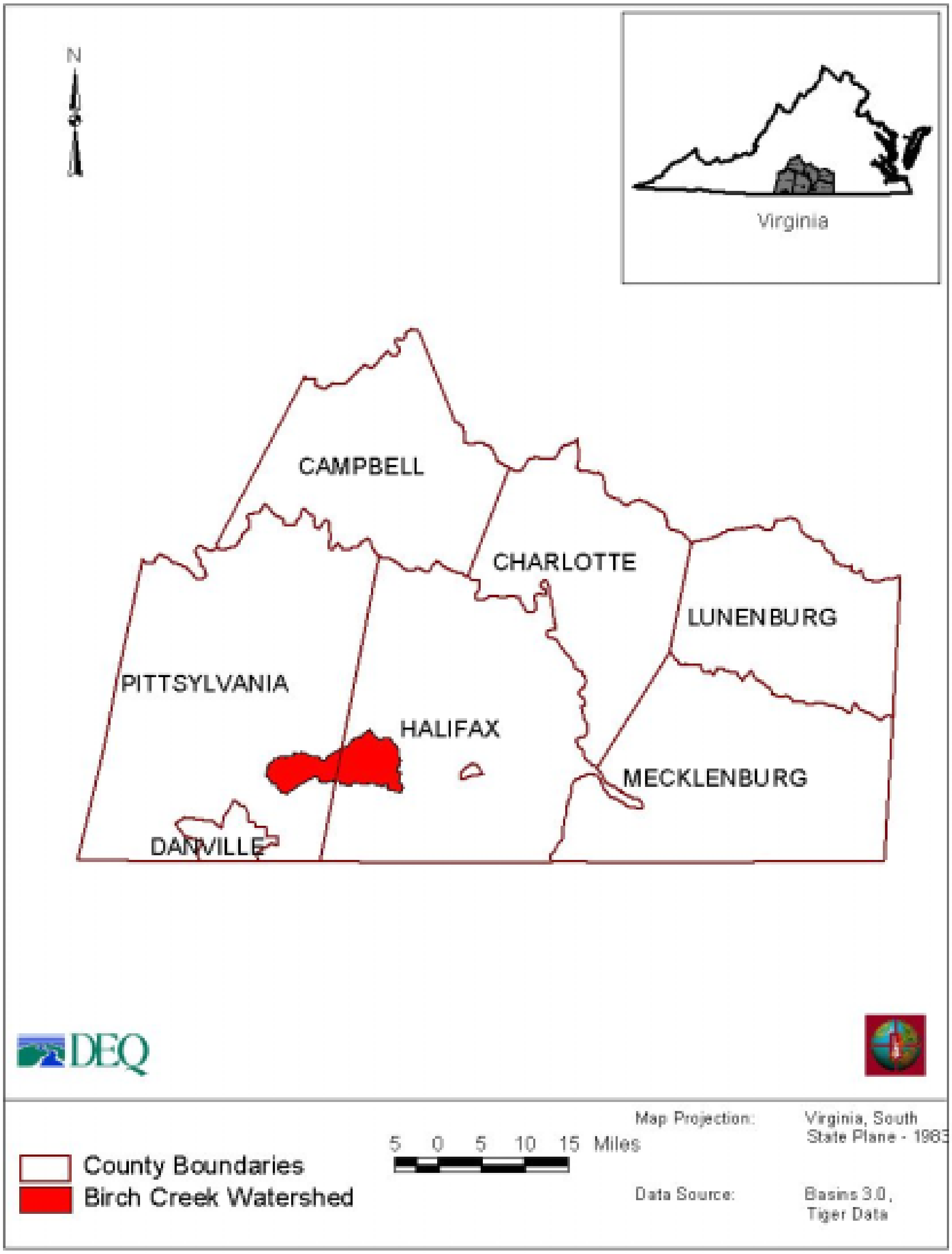
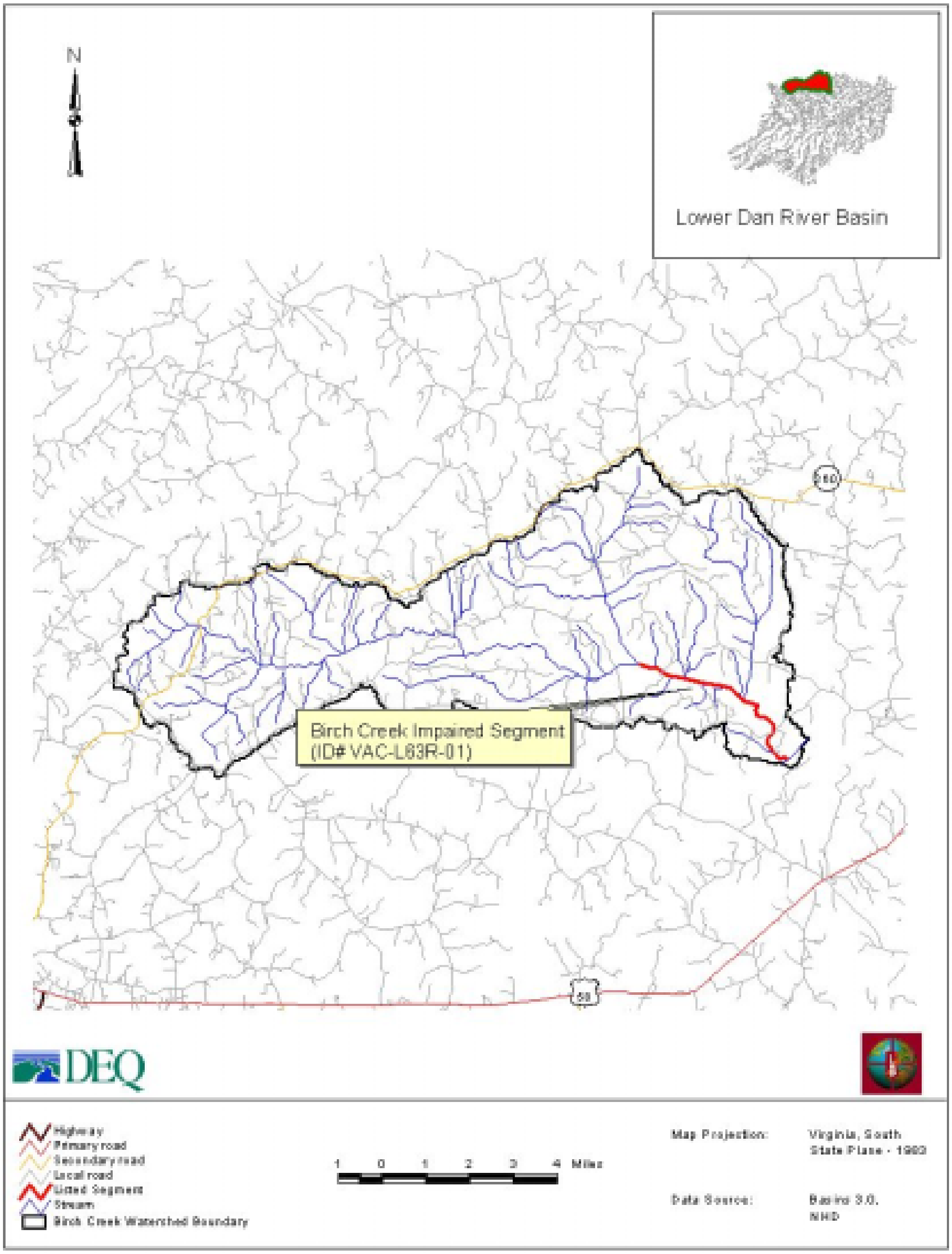


Figure 1-2: Birch Creek Watershed Listed Segments



1.3 Applicable Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A and also revised the disinfection policy of 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreational use, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples taken over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators have minimum of 12 data points or after June 30, 2008, whichever comes first."*

"E. coli bacteria shall not exceed a geometric mean of 126 per 100 ml of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 ml of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."

These criteria were adopted because there is a stronger correlation between the concentration of E. coli and the incidence of gastrointestinal illness than with fecal coliform. E. coli are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, E. coli has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to E. coli criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream E. coli criteria. The fecal coliform model and in-stream translator are used to calculate E. coli TMDLs. The following regression based in-stream translator is used to calculate E. coli concentrations from fecal coliform concentrations.

$$\text{E. coli concentration (cfu/100 ml)} = 2^{-0.0172} \times (\text{FC concentration (cfu/100ml)})^{0.91905}$$

For Birch Creek, the TMDL is required to meet both the monthly geometric mean and instantaneous criterion. The modeled fecal coliform concentrations are converted to E. coli concentrations by using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Birch Creek, located within Pittsylvania and Halifax counties in Virginia, was initially placed on the 2002 303(d) list for violations of the fecal coliform standards for contact recreation uses. Upon review of special study water quality data, the 2002 303(d) was modified to include 4.83 miles of Birch creek, beginning at its confluence with Carlton Creek and ending at the mouth of Birch Creek at the Dan River.

One of the first steps in developing TMDLs is determining the numeric endpoints, or water quality goals/targets, for each waterbody. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Birch Creek TMDL are established in the Virginia Water Quality Standards (9 VAC 25-260-20), which states that all waters in the state should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore the current water quality target for Birch Creek, as stated in 9 VAC 25-260-170.A and 9 VAC 25-260-170.B (Chapter 1), is an E. coli count where the geometric mean is not greater than 126 counts per 100 ml for two or more water quality samples taken during any calendar month, and does not exceed the instantaneous standard of 235 counts per 100 ml at any time.

2.2 The Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Birch Creek. If the TMDL is developed such that the water quality targets are met under the critical condition, then the water quality targets would be met under all other conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Birch Creek is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

Birch Creek flows through a predominantly rural setting, with very little urban land present in the watershed. Run-off from livestock grazing, manure applications, industrial processes, residential waste, and failed septic systems can contribute to increased levels of bacteria in the surface waters.

Fecal coliform loadings result from sources that can contribute during wet weather and dry weather. The critical condition of Birch Creek was determined from the available in-stream water quality data, as well as bacteria source tracking (BST) data collected by DEQ from December 2002 to November 2003, and USGS stream flow data. Due to the recent adoption of E. coli as the indicator species for bacteria, bacteria data were expressed as E. coli and not as fecal coliform; as previously stated, for this TMDL fecal coliform concentrations were modeled and then translated to E. coli concentrations. Stream flow data were not available for Birch Creek; therefore, these data were obtained using the paired watershed approach. A complete description of the paired watershed approach and the criteria used to select the paired watershed is presented in Chapter 4. Falling River was chosen as the paired watershed, and USGS gauging station # 02064000, located on the mainstem of Falling River, was used as the source of stream flow data.

Plotting bacteria water quality data along with stream flow data showed that the water quality standard violations occurred predominantly during low flow conditions. Figure 2-1 depicts E. coli concentrations at water quality station 4-ABIR001.00, the monitoring station with the most existing data, plotted with Falling River stream flow data. The data presented were collected from January 1995 to December 2000.

Bacteria source tracking data were also plotted to examine seasonal trends related to hydrologic conditions. These data showed that elevated E. coli concentrations were observed under both low flow and high flow conditions. Figure 2-2 depicts E. coli concentrations at the 3 BST monitoring stations, plotted with Falling River stream flow data.

Therefore, because elevated E. coli concentrations occurred under both wet weather and dry weather conditions, it is necessary for the critical condition to consider both of these conditions. Direct sources, which dominate under dry weather conditions, and indirect sources, which dominate under wet weather conditions, both have to be reduced in order to meet the geometric mean and instantaneous standards.

Figure 2-1: E. coli Concentrations at Monitoring Station 4-ABIR001.00 on Birch Creek and Falling River Stream Flow

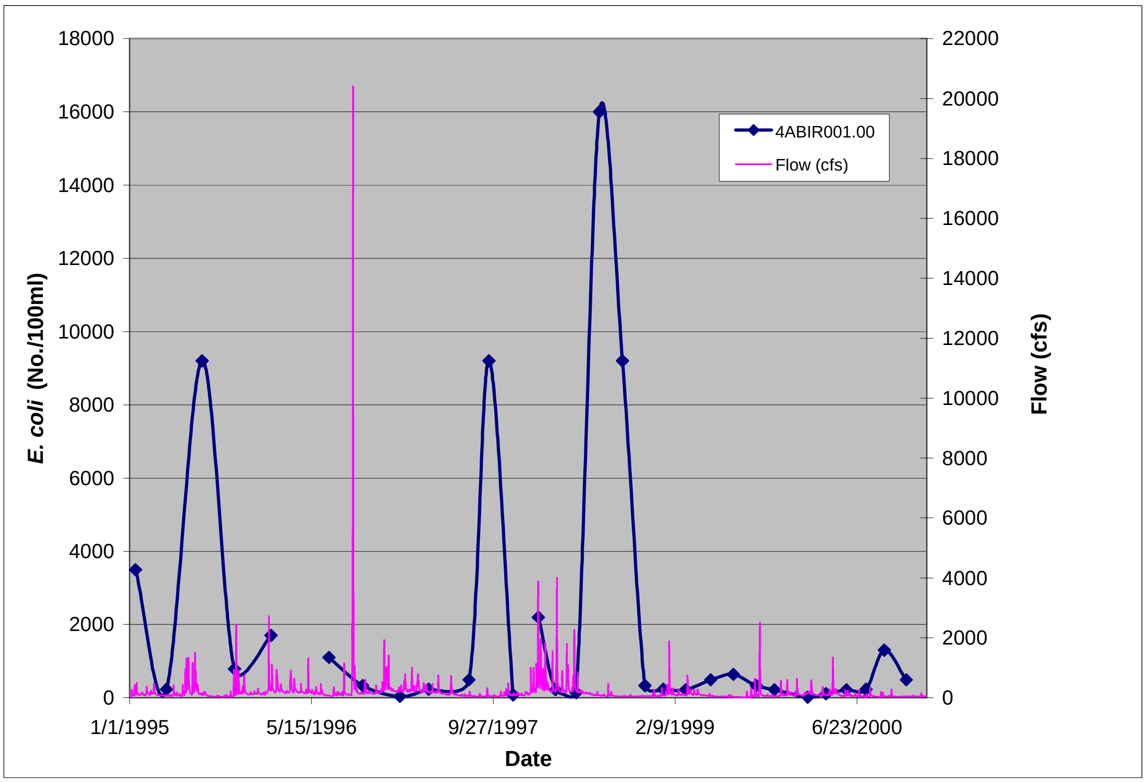
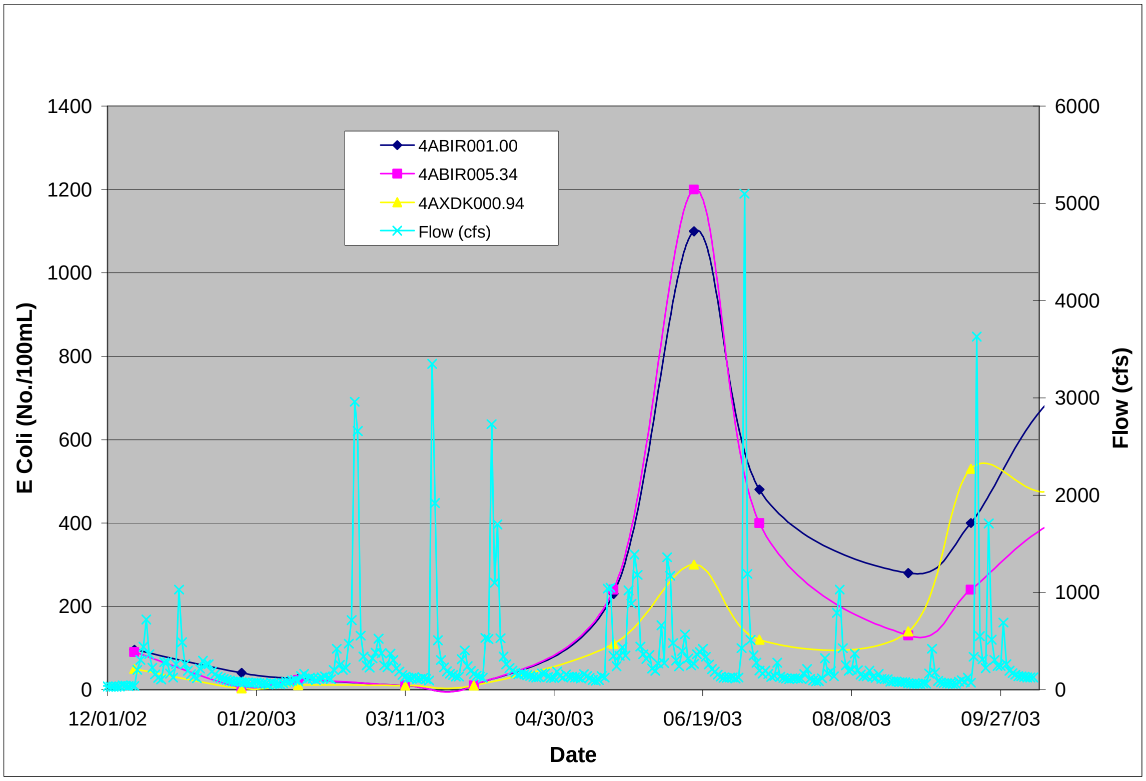


Figure 2-2: E. coli Concentrations from Bacteria Source Tracking Conducted at Water Quality Monitoring Stations on Birch Creek, and Falling River Stream Flow



2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

3.0 Watershed Description and Sources Assessment

In this section, the types of data available and information collected for the development of the Birch Creek TMDL are presented. This information was used to characterize Birch Creek and its watershed and to inventory and characterize the potential point and non-point sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Watershed physiographic data that describe the watershed physical conditions such as the topography, soils, and land use

(2) Hydrographic data that describe the stream physical conditions, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data and information related to the use and activities in the watershed that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe the stream flow and the water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Birch Creek TMDL.

Table 3-1: Inventory of Data and Information Used in the Birch Creek TMDL Development

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, Halifax SWCD, Pittsylvania SWCD, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Department of Health, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS, Halifax SWCD, Pittsylvania SWCD
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMR)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient instream monitoring data	DEQ
	Stream flow data	USGS, DEQ

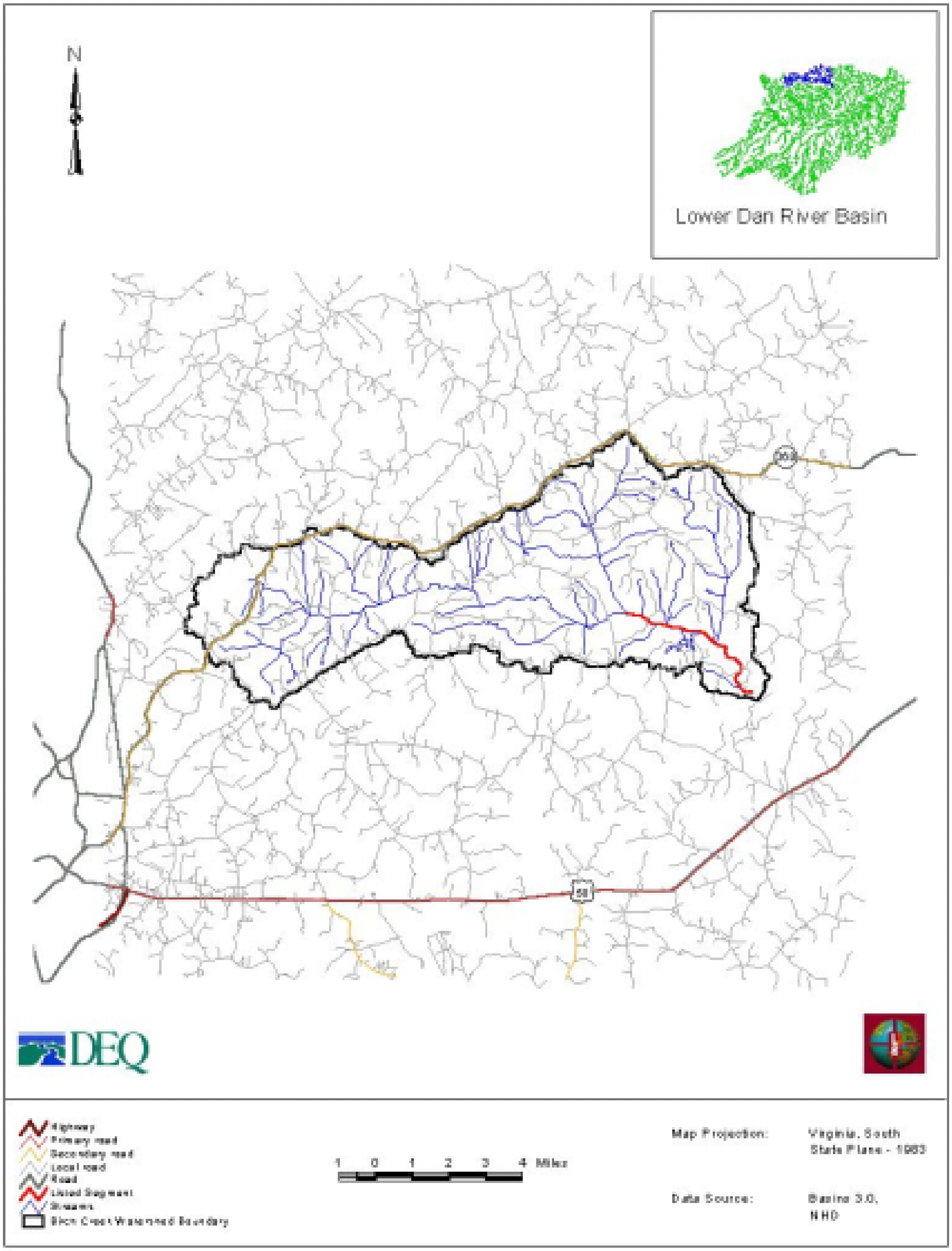
Notes
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
DSWC: Division of Soil and Water Conservation
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

3.2.1 Watershed Boundaries

Birch Creek is a tributary of the Lower Dan River Basin. The Birch Creek watershed is approximately 40,620 acres, or 63.5 square miles. The watershed is located within Pittsylvania and Halifax counties in Virginia. Approximately 41.5 percent of the drainage basin is located in Pittsylvania County; the remainder of the watershed is located in Halifax County. The Birch Creek watershed makes up about 2.7 percent of the land area in Pittsylvania County, and 4.5 percent of the land area in Halifax County. State Highway 360 (SH-360) runs through the northern boundary of the watershed in an east to west direction. Figure 3-1 is a map showing the location and the boundary of the watershed.

Figure 3-1: Location and Boundary of the Birch Creek Watershed



3.2.2 Topography

A digital elevation model (DEM) and USGS 7.5 minute quadrangle maps were used to characterize the topography in the watershed. DEM data were obtained from BASINS and compared to the Pittsylvania and Halifax, Virginia USGS 7.5 minute quadrangle maps. Elevation in the watershed ranged from 315 to 825 feet above mean sea level.

3.2.3 Soils

The Birch Creek watershed soil characterization was based on data obtained from BASINS. There are two dominant soil associations present in the Birch Creek watershed: Cecil-Madison-Enon and Iredell-Poindexter-Pacolet. The majority of the watershed is comprised of Cecil-Madison-Enon soils. Cecil-Madison-Enon soils are fine, well-drained mineral soils derived from felsic parent materials. Iredell-Poindexter-Pacolet soils are fine, moderately well-drained to well-drained soils formed in material weathered from felsic parent materials or fine-grained rocks of the Triassic Basin. The distribution of soils in the Birch Creek watershed is presented in Table 3-2.

Table 3-2: Soil Types and Characteristics in the Birch Creek Watershed

Map Unit ID	Soil Association	Percent	Hydrologic Soil Group
VA019	Cecil-Madison-Enon	90.7	B/C
VA029	Iredell- Poindexter-Pacolet	8.5	C/D/B
VA033	Turbeville-Dogue-Edgehill	0.8	B/C

Source: NRCS

The hydrologic soil group linked with each soil association is also presented in Table 3-2. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group “A” designates soils that are well to excessively well drained, whereas hydrologic soil group “D” designates soils that are poorly drained. This means that soils in hydrologic group “A” allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in Table 3-3.

Table 3-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

3.2.4 Land Use

Land use characterization was based on National Land Cover Data (NLCD), developed by USGS. The distribution of land uses in Birch Creek, by land area and percentage, is presented in Table 3-4. Dominant land uses in the watershed are forested land (71%) and hay/pastureland (19%), which account for a combined 90% of the land area in the Birch Creek watershed. Brief descriptions of the land use types are presented in Table 3-5.

Figure 3-2 depicts the land use distribution within the watershed. Forested lands and hay/pasturelands are evenly dispersed throughout the watershed.

Table 3-4: Land Use Distribution in Birch Creek Watershed

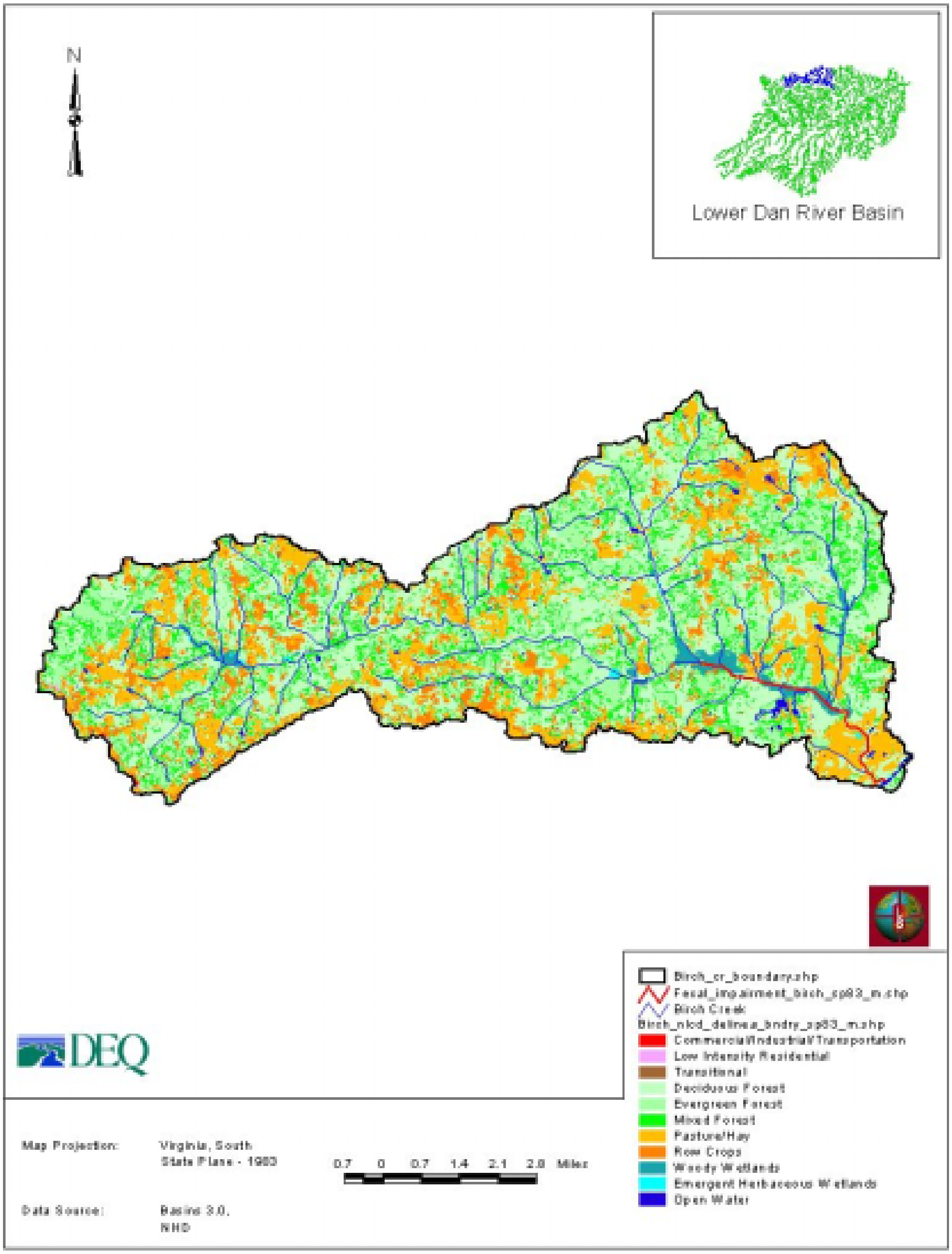
Land Use Category	Land Use Type	Acres	Percent of Watershed's Land Area
Water/Wetlands	Open Water	185.4	0.46
	Woody Wetlands	800.2	1.97
	Emergent Herbaceous Wetlands	71.0	0.17
Urban	Low Intensity Residential	18.8	0.05
	Commercial/Industrial/Transportation	10.5	0.03
Agriculture	Pasture/Hay	7645.1	18.82
	Row Crop	2473.8	6.09
Forest	Deciduous Forest	15653.5	38.54
	Evergreen Forest	6873.3	16.92
	Mixed Forest	6082.3	14.97
Other	Transitional	803.8	1.98
Total		**40,618**	**100**

Table 3-5: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/Industrial/Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: NLCD

Figure 3-2: Land Use in the Birch Creek Watershed



3.3 Stream Flow Data

Because there was not a stream flow gauge or other source of stream flow data present for Birch Creek, a paired watershed approach was used to set up and calibrate the HSPF model. The basis of this approach was to develop a model for a hydrologically similar watershed, where sufficient stream flow and other data were available. This hydrologically calibrated model was then transferred to Birch Creek. Criteria used to evaluate the hydrologic similarity of the paired watersheds included physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use/land cover) and mean annual precipitation.

Using the criteria mentioned above, Falling River, located within the Roanoke River Basin, was chosen because of its hydrologic and physiographic similarities to Birch Creek. The flow monitoring station for Falling River (USGS2064000) is located near Naruna, Virginia. Flow data for Falling River were retrieved for the period of 1929 to 2003 from the U.S. Geological survey, and were used in model set-up, hydrological calibration, and model validation. The calibrated model was then transferred to the Birch Creek watershed.

A detailed discussion of the paired watershed approach and a presentation of the similarities between Falling River and Birch Creek are presented in Chapter 4.

3.4 In-Stream Water Quality Monitoring

Water quality data for the Birch Creek watershed was obtained from DEQ, which conducted sampling at five water quality monitoring stations located within the basin. The location of these stations are summarized in Table 3-6, and depicted in Figure 3-3.

Table 3-6: In-Stream Water Quality Monitoring Stations Located in the Birch Creek Watershed

No.	Station Id	Station Location	Stream Name	River Mile
1	4-ABIR001.00	Birch Creek at Route 659 Bridge	Birch Creek	1.00
2	4-ABIR004.22	Birch Creek at Route 685 Bridge	Birch Creek	4.22
3	4-ABIR005.34	Birch Creek at Route 662-Birch-Elmo Rd.	Birch Creek	5.34
4	4-ABIR011.55	Birch Creek at Route 729-Kentuck Rd.	Birch Creek	11.55
5	4-ABIR014.28	Birch Creek at Route 713-Birch Creek Rd.	Birch Creek	14.28

Ambient water quality data for station 4-ABIR005.34 were not available. For the other stations, Table 3-7 lists the water quality sampling period of record, the number of fecal coliform samples collected, the minimum and the maximum observed concentrations, and the percent violation of the water quality standard. Water quality data collected at stations with multiple samples indicate that violation of the fecal coliform standard ranged from 28 to 56 percent.

Figure 3-3: Birch Creek Watershed Water Quality Monitoring Stations

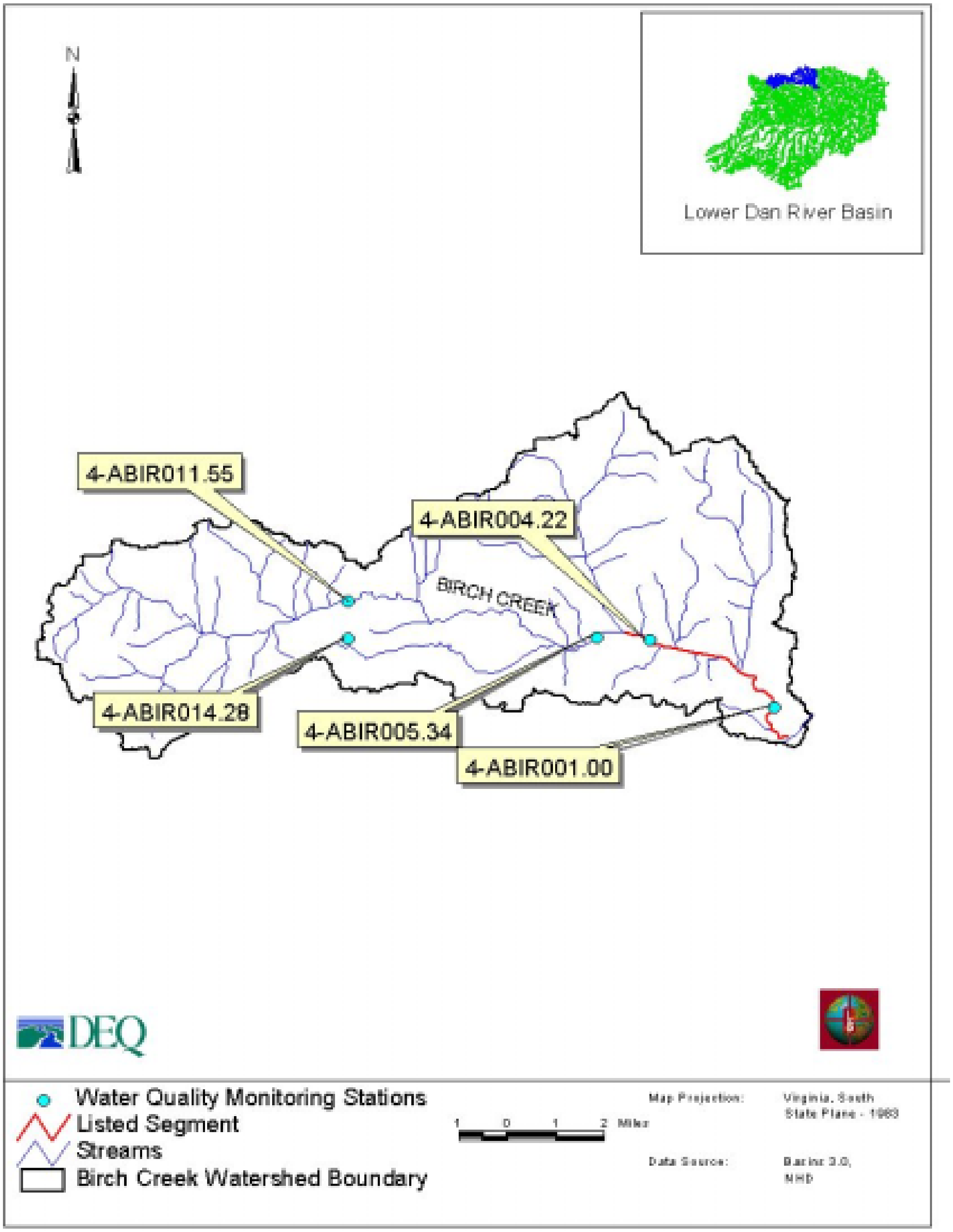


Table 3-7: Summary of Fecal Coliform Sampling Conducted in the Birch Creek Watershed

No.	Station Id	Period of Record	Number of Samples	Minimum (cfu/100ml)	Maximum[1] (cfu/100ml)	Violation[2] (%)
1	4-ABIR001.00	1993-2001	39	18	16,000	28
2	4-ABIR004.22	2002-2003	12	50	1,500	56
3	4-ABIR011.55	2002-2003	12	50	1,750	56
4	4-ABIR014.28	2002-2003	12	50	4,000	56

1: Samples were censured at 16,000 cfu/100ml.
2: The percent violation for geometric mean standard applies to samples collected during any calendar month. The instantaneous standard was used when the sampling frequency was more than 30 days.

3.4.1 Bacteria Source Tracking

As part of the Birch Creek TMDL development, Bacteria Source Tracking (BST) sampling was conducted at three locations in the Birch Creek Watershed. The objective of BST was to identify the sources of fecal coliform in the listed segment of Birch Creek. Subsequently, this information was used in the model set-up, and in the distribution of the fecal coliform loading among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as "DNA fingerprinting", and are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by organisms. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Birch Creek TMDL, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

Bacterial source tracking was conducted at three stations on Birch Creek; one station (4-ABIR001.00) was located at the intersection of the creek with the Route 659 Bridge, another (4-ABIR005.34) at the intersection of the creek with Route 662, Birch Elmo road, and the third (4-AXDK000.94) at the intersection of an unnamed tributary of Birch Creek and Route 683. Location of the BST sampling stations are shown in Figure 3-4. Samples were collected and analyzed monthly from December 2002 through November 2003, for a total of 12 sampling events at each station. Results of BST testing at the three stations are presented in Table 3-8.

Four categories of fecal bacteria sources were considered: human, wildlife, livestock and pet. BST samples collected on March 11, 2003 and April 3, 2003 were below detection limits at all three stations. Results for the remaining 10 sampling events at each station are presented in Table 3-8. The data indicate that E. coli from human, wildlife, livestock, and pet sources were present in Birch Creek. The human signature ranged from 0 to 100 percent, the wildlife signature ranged from 0 to 79 percent, the livestock signature ranged from 0 to 100 percent, and the pet signature ranged from 0 to 59 percent.

Figure 3-4: Birch Creek Watershed Bacteria Source Tracking Sampling Stations

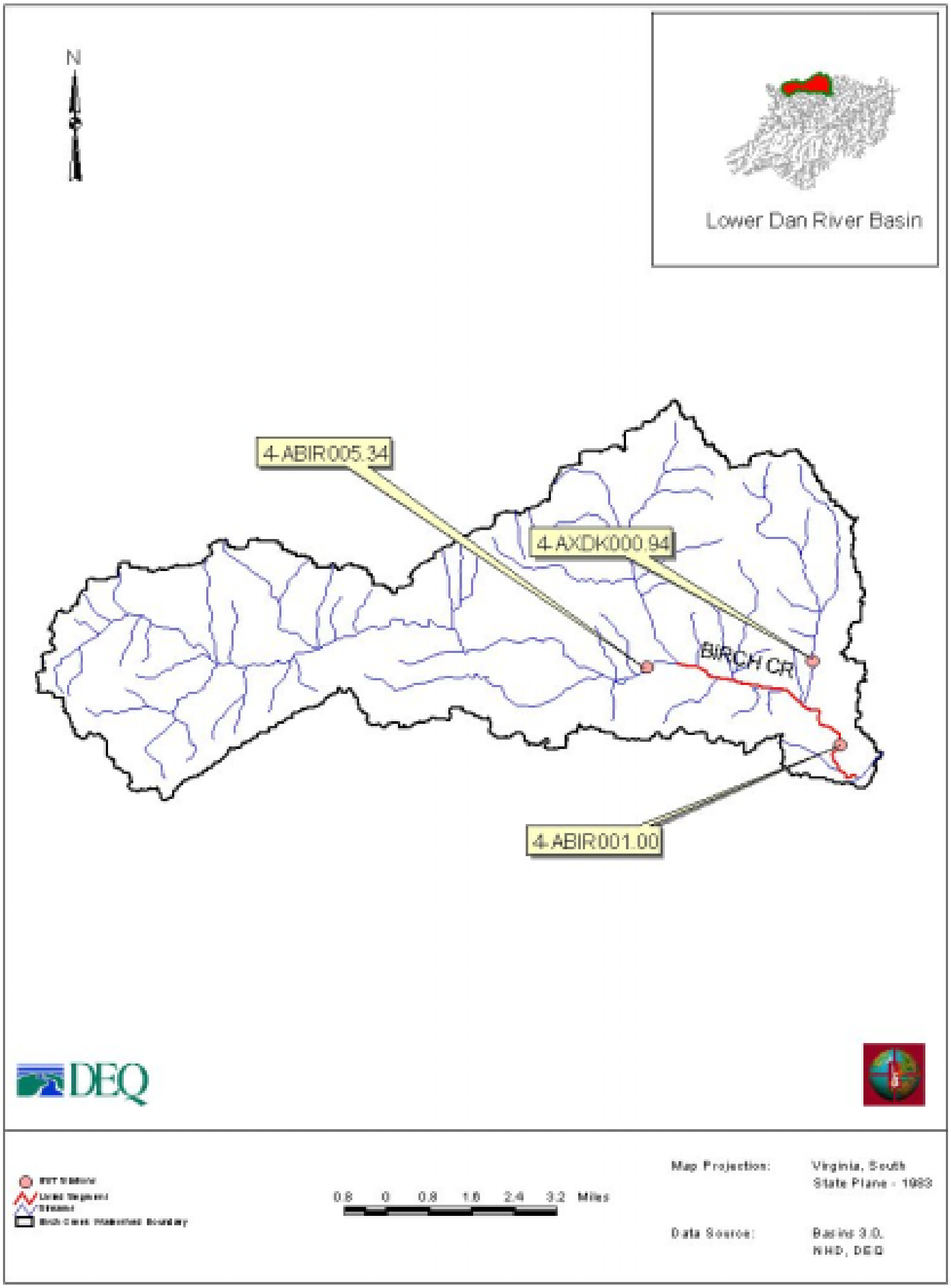


Table 3-8: Results of BST Analysis Conducted in the Birch Creek Watershed

Location	Date	E-coli cfu/100ml	Percent of Enterococci Classified as			
			Wildlife	Human	Livestock	Pet
4ABIR001.00 (Mainstem)	12/10/02	96	17%	46%	33%	4%
	01/15/03	40	4%	29%	63%	4%
	02/03/03	26	14%	5%	67%	14%
	05/20/03	230	17%	8%	25%	50%
	06/16/03	1100	21%	0%	71%	8%
	07/08/03	480	50%	4%	29%	17%
	08/27/03	280	25%	21%	41%	13%
	9/17/2003	400	38%	0%	62%	0%
	10/15/2003	700	46%	0%	42%	12%
	11/20/2003	720	67%	0%	12%	21%
4ABIR005.34 (Mainstem)	12/10/02	90	4%	0%	67%	29%
	01/15/03	6	20%	80%	0%	0%
	02/03/03	23	10%	10%	75%	5%
	05/20/03	240	17%	4%	62%	17%
	06/16/03	1200	25%	4%	58%	13%
	07/08/03	400	37%	33%	13%	17%
	08/27/03	130	29%	4%	54%	13%
	9/17/2003	240	42%	0%	58%	0%
	10/15/2003	400	29%	17%	50%	4%
	11/20/2003	430	79%	0%	17%	4%
4AXDK000.94 (Tributary)	12/10/02	50	21%	0%	62%	17%
	01/15/03	3	0%	100%	0%	0%
	02/03/03	11	0%	0%	100%	0%
	05/20/03	110	8%	0%	33%	59%
	06/16/03	300	54%	0%	38%	8%
	07/08/03	120	57%	13%	13%	17%
	08/27/03	140	21%	0%	38%	41%
	9/17/2003	530	42%	0%	54%	4%
	10/15/2003	480	21%	21%	46%	12%
	11/20/2003	740	33%	0%	29%	38%

3.5 Fecal Coliform Sources Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Birch Creek watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, land application of manure and biosolids, wildlife, and pets. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

Based on data and information obtained from DEQ's West Central Regional Office, there are no permitted facilities located in the Birch Creek watershed.

3.5.2 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on the USGS 7.5 minute quadrangle maps and the U.S. Census Bureau data.

The Pittsylvania and Halifax, Virginia USGS 7.5 minute quadrangle maps were combined and used to create a single map that covers the entire Birch Creek watershed. The structures on the USGS maps were digitized and converted to a GIS layer. The number of digitized structures in the watershed was 1,334. However, this number does not reflect the number of households; it had to be corrected based on the census data to account for population growth and structures classified as non-residential. Since there is no sewer network in the watershed, all houses in the watershed are on septic systems. The USGS maps were dated 1964-1968, with photo revision dated 1982-1990. Therefore, it was assumed that the structures on these maps are at least 15 years old or more.

Historical and current U.S. Census Bureau data for Pittsylvania and Halifax counties were reviewed to establish the population growth rate in the two counties and to validate the housing unit calculation. Comparison of the number housing units specified in the 1990 census to the digitized structures indicated that about 22% of the digitized structures are not residential or households. In this largely farming community, these non residential structures can be farmstead areas or barns. The adjusted number of structures was projected using the population growth rates for the two counties for the period from 1990 to 2000 and taking into account that the watershed makes up about 2.7 percent and 4.5 percent of land area in Pittsylvania County and Halifax County, respectively. The total number of households in the watershed based on this calculation was estimated at 1,317. Using this number of households and the average household densities for the two counties (see Table 3-9), the watershed population estimates agreed with the 2000 US Census data. As previously mentioned, all of these households in the watershed are on septic systems.

Table 3-9: US Census Summary for Halifax and Pittsylvania Counties

U.S. Census Data - 2000	County	
	Halifax	Pittsylvania
Population	37,355	61,745
# Households	15,018	24,684
# Housing Units	16,953	28,011
Population density (persons per square mile)	45	64
Household density (persons per household)	2.43	2.49

3.5.2.1 Failed Septic Systems

To determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rates were determined based on the total amount of septic systems versus the number of applications for new systems and the number of repairs to existing systems in Pittsylvania and Halifax Counties. Table 3-10 shows the number of applications for new systems as well as the number of repairs over the last eight years in Pittsylvania and Halifax Counties. These data were combined with the population data to establish the rate of applications for new septic systems and the rate of repair of existing septic systems in the watershed. Table 3-11 and Table 3-12 show the rate of applications for new septic systems in Pittsylvania and Halifax Counties ranged from 1.7 to 3.5 percent from 1995 to 2002. For the same period, the data indicate that the rate of septic system repair permits ranged from 0.18 to 0.65 percent. This low rate may be attributed to a large number of septic system repairs being performed without obtaining a permit.

Table 3-10: Number of Applications for New Septic Systems and Number of Repairs in Pittsylvania and Halifax Counties (including outside the Birch Creek Watershed)

Year	Applications for New Septic Systems		Repairs of Existing Systems	
	Pittsylvania	Halifax	Pittsylvania	Halifax
1995	780	411	98	56
1996	732	337	135	49
1997	727	353	157	53
1998	851	326	123	46
1999	844	329	77	35
2000	796	350	94	59
2001	625	319	98	52
2002	542	254	45	33
Average	**737**	**335**	**103**	**48**

Table 3-11: Rates of Applications for New Septic Systems and Rates of Repairs in Pittsylvania County (including outside the Birch Creek Watershed)

Year	Households in Pittsylvania County	% New	% Repair
1995	23,543	3.3	0.42
1996	23,788	3.1	0.57
1997	24,037	3.0	0.65
1998	24,288	3.5	0.51
1999	24,541	3.4	0.31
2000	24,684	3.2	0.38
2001	24,851	2.5	0.39
2002	24,904	2.2	0.18

*Calculations based on 2.49 persons per household from the 2000 census.

Table 3-12: Rates of Applications for New Septic Systems and Rates of Repairs in Halifax County (including outside the Birch Creek Watershed)

Year	Households in Halifax County	% New	% Repair
1995	13,552	3.0	0.41
1996	13,898	2.4	0.35
1997	14,253	2.5	0.37
1998	14,617	2.2	0.31
1999	14,990	2.2	0.29
2000	15,018	2.3	0.39
2001	15,257	2.1	0.34
2002	15,142	1.7	0.22

*Calculations based on 2.43 persons per household from the 2000 census.

A detailed discussion of the failure rates, flows, and fecal coliform concentrations of septic systems is presented in Chapter 4.

3.5.3 Livestock

An inventory of the livestock residing in the Birch Creek watershed was conducted using data and information provided from the DCR, Halifax and Pittsylvania Soil and Water Conservation Districts, NRCS, and field surveys. The data and information indicate the following:

- beef cattle operations exist on pasture areas throughout the watershed
- no feedlots are located in the watershed
- no dairy operations exist in the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the stream
- other livestock are present in the watershed

Table 3-13 summarizes the livestock inventory in the watershed.

Table 3-13: Birch Creek Watershed Livestock Inventory

Livestock Type	Total Number of Animals
Beef Cattle	1,169
Horse	16

Sources: DCR, Halifax and Pittsylvania Soil & Water Conservation Districts, field surveys, Birch Creek stakeholders

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. Table 3-14 shows the average fecal coliform load contributed by each type of livestock, expressed as production per animal per day.

Table 3-14: Daily Fecal Coliform Production of Livestock

Source	Daily Fecal Production (in millions of cfu/day)
Beef Cattle	33,000
Horse	420

Sources: ASAE, 1998; Metcalf and Eddy, 1979; Map Tech, Inc., 2000; EPA, 2001.

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Birch Creek TMDL, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the public meetings, where stakeholders provided comments. The monthly schedule was adjusted to reflect conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in Table 3-15. The time beef cattle spend in the pasture was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from beef cattle was based on the amount of time they spend in the stream.

Table 3-15: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002

Based on field surveys and interviews, it was determined that other livestock spend minimal time in confinement and in the stream. Therefore, fecal coliform loading from other livestock was considered a land-based source, and was calculated based on the number of livestock in each subwatershed and the daily fecal coliform production per animal.

3.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Since there are no dairy operations in the watershed, and the beef cattle spend a large portion of their day on pasturelands, land application of manure was not included in the Birch Creek TMDL.

3.5.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Although there is no sewage treatment plant located in the Birch Creek watershed, biosolids from the Danville Sewage Treatment plant and the Chatham Sewage Treatment plant are applied in the form of liquid or solid. Based on data obtained from the Virginia Department of Health, 1,143 dry tons (5,031,560 gallons) of liquid biosolids and 2,208 dry tons (6,665 wet tons) of solid biosolids were applied to 76 fields in Pittsylvania County in the year 2000. Biosolids were not applied to any fields in Halifax County that year. In 2001, 1,417 dry tons (5,759,619 gallons) of liquid biosolids and 745 dry tons (2,349 wet tons) of solid biosolids were applied to 53 fields in Halifax County, and 2,362 dry tons (9,492,294 gallons) of liquid biosolids and 940 dry tons (2,903 wet tons) of solid biosolids were applied to 66 fields in Pittsylvania County. Because there was no available information on whether these fields were located within the Birch Creek watershed, for TMDL development it was assumed that 50 percent of the biosolids were applied in the Birch Creek watershed.

A detailed discussion of the biosolids application rates is presented in Chapter 4

3.5.6 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in Table 3-16.

Table 3-16: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	
Goose	0.004 animals/acre	Within 66 feet of streams and ponds
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001.

The wildlife inventory presented in Table 3-17 was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-17: Birch Creek Watershed Wildlife Inventory

Wildlife type	Number of Animals
Deer	1,917
Raccoon	1,085
Muskrat	4,691
Beaver	512
Goose	7
Mallard	3
Wood duck	3
Wild Turkey	408

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. Table 3-18 shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream, also shown in Table 3-18.

Table 3-18: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Mallard	2,430	50
Wood Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.7 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to Birch Creek. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Birch Creek watershed was estimated based on the number of households in the watershed, assuming an average of 1.7 dogs and 2.2 cats per household. As previously presented, the total number of households in the watershed was estimated to be 1,317. Therefore it was estimated that a total of 2,897 cats and 2,239 dogs were present in the watershed.

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on the daily fecal coliform production rates of 504 cfu/day per animal for cats and 4.09 $x10^9$ cfu/day per animal for dogs.

3.6 Existing Best Management Practices

Information about the existing best management practices (BMPs) in the Birch Creek watershed was compiled during interviews with the NRCS, Halifax and Pittsylvania Soil and Water Conservation Districts, and DCR staff. The BMP information compiled from the interviews was compared to BMP GIS data obtained from DCR. Table 3-19 is a list of BMP types in the Birch Creek watershed. Figure 3-5 presents the location of these BMPs in the watershed.

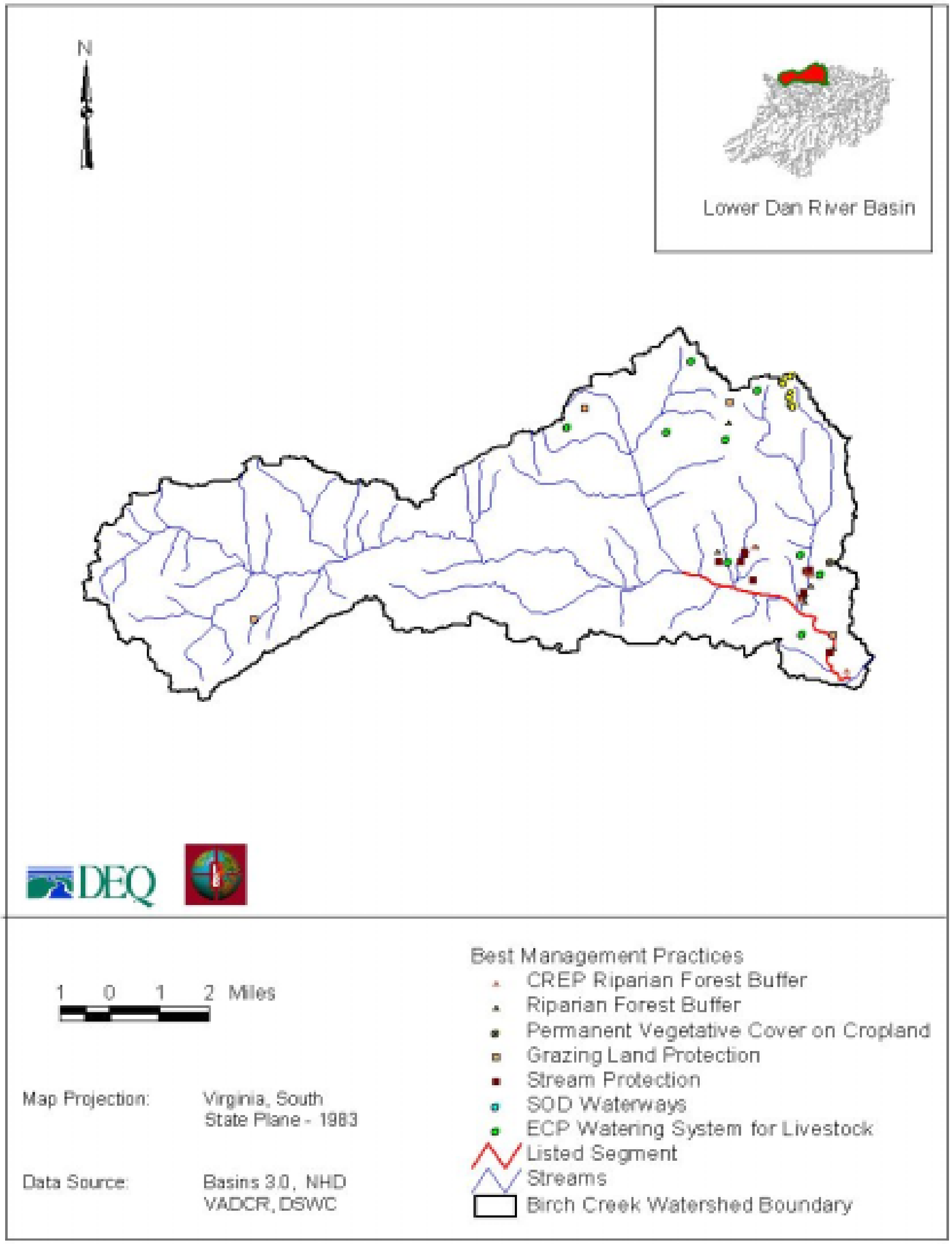
BMPs present in the Birch Creek watershed include Permanent Vegetation Cover on Cropland, CREP Riparian Forest Buffer, Riparian Forest Buffer, Grazing Land Protection, Sod Waterways, and Stream Protection. Also, ECP Watering Systems for Livestock were present in the lower half of the watershed.

Table 3-19: Inventory of Existing BMPs in the Birch Creek Watershed

BMP	Code[1]	Number
CREP Riparian Forest Buffer	CP-22	27
Riparian Forest Buffer	CRFR-3	29
Permanent Vegetative Cover on Cropland	SL-1	1
Grazing Land Protection	SL-6	4
Stream Protection	WP-2	22
SOD Waterways	WP-3	7
ECP Watering System for Livestock	----	9

1: The BMP codes are defined in Virginia Agricultural BMP Manual, 2003, Department of Conservation and Recreation, Richmond, VA.
Source: DCR, 2003 and SWCD, 2003.

Figure 3-5 : Best Management Practices (BMPs) in Birch Creek Watershed



4.0 Modeling Approach

This section describes the modeling approach used in the Birch Creek TMDL development. The primary focus is on the sources representation in the model, assumptions used, the model set-up, calibration and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the waterbody that can:

- represent the watershed characteristics
- represent the point and non-point sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of Birch Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Birch Creek model were used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the following sections.

4.3 Watershed Boundaries

Birch Creek is a tributary of the Lower Dan River Basin. The Birch Creek watershed is approximately 40,620 acres, or 64 square miles. The watershed is located within Pittsylvania and Halifax counties of Virginia. Approximately 42 percent of the total watershed is located in Pittsylvania County; the remainder is located in Halifax County. The watershed makes up about 2.7 percent of the land area in Pittsylvania County, and 4.5 percent of the land area in Halifax County. State Highway 360 (SH-360) runs through the northern boundary of the watershed in an east to west direction. Figure 4-1 is a map showing the Birch Creek watershed boundaries.

4.4 Watershed Delineation

For this TMDL, the Birch Creek watershed was delineated into 20 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. The sizes of the 20 subwatersheds are presented in Table 4-1. Figure 4-2 is a map showing the delineated subwatersheds for Birch Creek.

Figure 4-1: Birch Creek Watershed Boundary

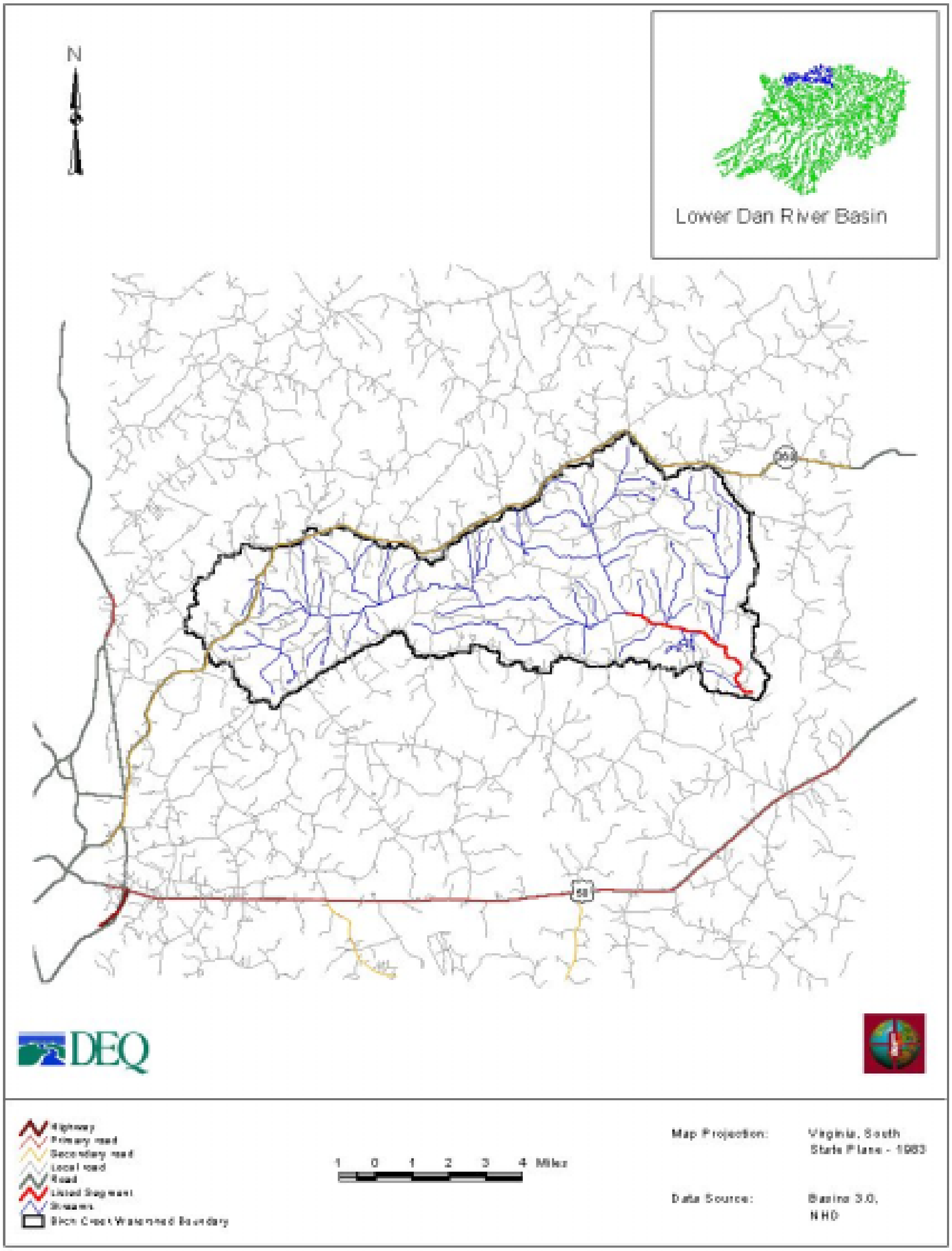
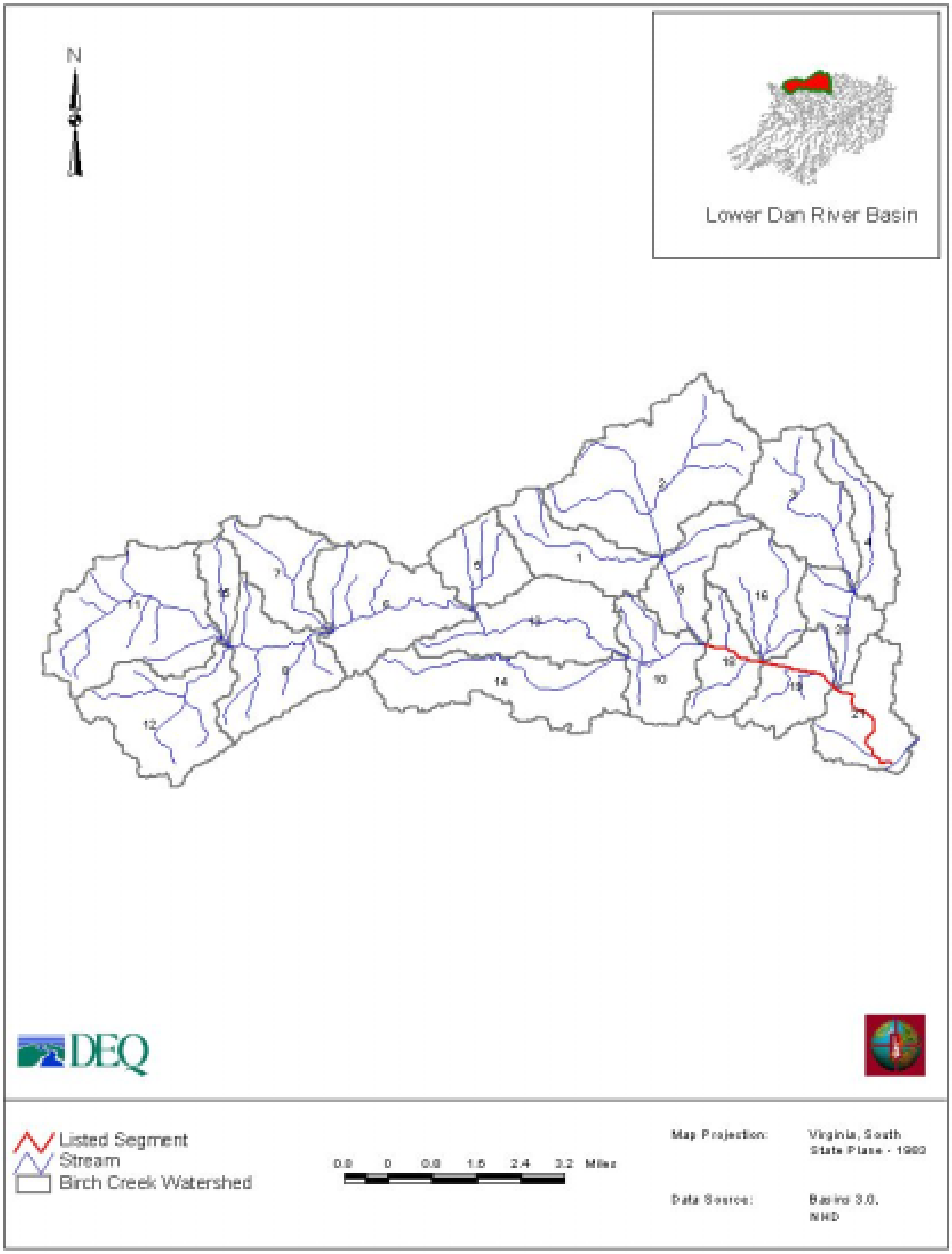


Table 4-1: Birch Creek Delineated Subwatersheds

Number	Model Subshed ID	Drainage Area (acres)
1	1	1730
2	2	4647
3	3	2280
4	4	1323
5	5	1320
6	6	2767
7	7	1576
8	8	2219
9	9	1541
10	10	1574
11	11	3818
12	12	2675
13	13	2444
14	14	2927
15	15	650
16	16	1776
17	17	0
18	18	1257
19	19	1328
20	20	1130
21	21	1798
	Total	**40,780**

Figure 4-2: Birch Creek Subwatershed Delineation



4.5 Land Use Reclassification

As previously mentioned, land use characterization was based on National Land Cover Data (NLCD) developed by USGS. Land use data and the distribution of land uses in the Birch Creek watershed were presented in Chapter 3. There are 11 land use classes in the Birch Creek watershed; the dominant land uses are forested lands and hay/pasturelands. The original 11 land use types were consolidated into 7 land use categories to meet the modeling goals, to facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 11 land use types to a representative number of land use types that best describe conditions and the dominant fecal coliform source categories in the Birch Creek watershed. Land use reclassification was based on similarities in hydrologic and potential fecal coliform production characteristics. The reclassified land uses are presented in Table 4-2.

Table 4-2: Birch Creek Land Use Reclassification

Land Use Category	NLCD Land Use Type	Acres	Percent of Watershed's Land Area
Water	Open Water	185.4	0.46
Low Residential	Low Intensity Residential	18.8	0.05
Commercial/Industrial/ Transportation	Commercial/Industrial/Transportation	10.5	0.03
Cropland	Row Crop	2473.8	6.09
Unimproved Pasture	Pasture/Hay	7645.1	18.82
	Transitional	803.8	1.98
Forest	Deciduous Forest	15653.5	38.54
	Evergreen Forest	6873.3	16.92
	Mixed Forest	6082.3	14.97
Wetlands	Woody Wetlands	800.2	1.97
	Emergent Herbaceous Wetlands	71.0	0.17
Total		**40,617**	**100**

4.6 Hydrographic Data

Hydrographic data that describe the stream network and reaches were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Birch Creek are included in the RF3 database. Reach information for stream segments comprising the mainstem Birch Creek are provided in Table 4-3. Due to the size of this basin, reach information for the entire Birch Creek drainage is not presented in this report.

Table 4-3: Birch Creek RF3 Reach Information Summary

Reach Number	Reach Name	Length (Miles)
3010104 6 0.00	Birch Creek	0.44
3010104 6 0.41	Birch Creek	1.80
3010104 6 2.09	Birch Creek	0.07
3010104 6 2.16	Birch Creek	0.41
3010104 6 2.54	Birch Creek	0.44
3010104 6 2.95	Birch Creek	0.49
3010104 6 3.42	Birch Creek	0.29
3010104 6 3.69	Birch Creek	0.45
3010104 6 4.12	Birch Creek	0.39
3010104 6 4.49	Birch Creek	0.86
3010104 6 5.28	Birch Creek	0.16
3010104 6 5.43	Birch Creek	0.22
3010104 6 5.63	Birch Creek	0.29
3010104 6 5.89	Birch Creek	3.18
3010104 6 8.80	Birch Creek	0.51
3010104 6 9.26	Birch Creek	2.20
3010104 611.27	Birch Creek	0.47
3010104 611.70	Birch Creek	0.38
3010104 612.04	Birch Creek	0.05
3010104 612.09	Birch Creek	0.49
3010104 612.53	Birch Creek	0.13
3010104 612.65	Birch Creek	0.90
3010104 613.47	Birch Creek	0.29
3010104 613.74	Birch Creek	0.27
3010104 613.99	Birch Creek	1.37
3010104 615.24	Birch Creek	0.51
3010104 615.70	Birch Creek	1.30

The stream geometry was field surveyed for representative reaches of Birch Creek. The stage flow relationship that is required by HSPF was developed based on the USGS stream flow gage data for Falling River. The relationship was then transferred to the Birch Creek watershed based on the drainage area weighted method to determine the function tables (F-Tables) for the 140 total stream segments in the Birch Creek watershed.

Birch Creek and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the Birch Creek stream reach segments is presented in Appendix A.

4.7 Fecal Coliform Sources Representation

This section will show how the fecal coliform sources identified in Chapter 3 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

There are no permitted facilities present in the Birch Creek watershed.

4.7.2 Failed Septic Systems

Failed septic system loading to Birch Creek can be direct (point) or land-based (indirect or non-point) depending on the proximity of the septic system to the stream. In cases where the septic system is within the 20-foot stream buffer, the failed septic system was represented as a constant source (similar to a permitted facility) in the model.

As explained in Chapter 3, the total number of septic systems in the watershed was estimated at 1,317 systems. Based on GIS data, only 3 of the 1,317 households on septic systems were located in the 20-foot stream buffer. Therefore, the failed septic system load was considered a land-based load in the Birch Creek watershed.

For this TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of the watershed conditions. This corresponds to a total of 41 failed septic systems in the watershed. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 15 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR, DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data. The 1990 Census data indicated that 9.5 percent of houses in Halifax County and 6.0 percent of houses in Pittsylvania County are on neither sewers nor septic systems.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations. Fecal coliform loading from failed septic systems that are not within the 20 buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as constant sources of fecal coliform. Table 4-4 shows the distribution of the septic systems and the straight pipes in the Birch Creek watershed. The load from septic systems is presented in Appendix B.

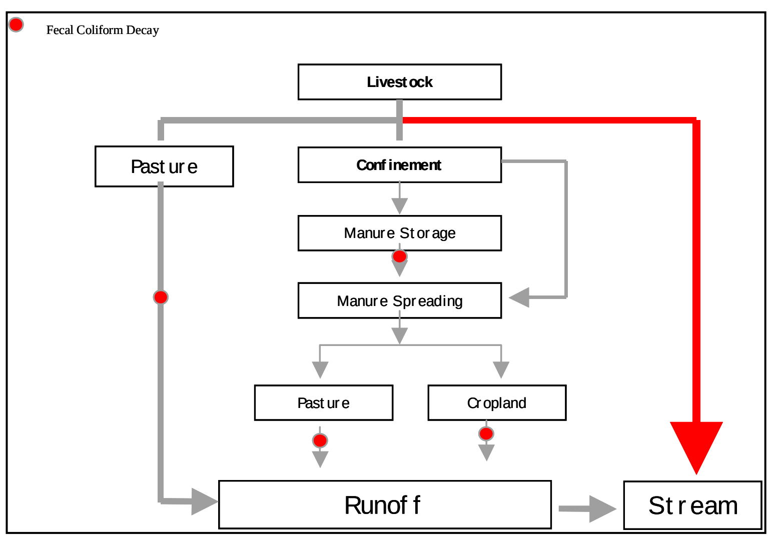
Table 4-4: Failed Septic Systems and Straight Pipes Assumed in Model Development

Model Subshed ID	Number of septic systems	Number of Failed Septic Systems	Number of straight pipes
1	27	1	1
2	103	3	1
3	28	1	1
4	16	0	0
5	22	1	0
6	54	2	1
7	89	3	1
8	165	5	2
9	24	1	0
10	25	1	0
11	270	7	3
12	243	7	3
13	18	1	0
14	103	3	1
15	52	2	1
16	21	1	0
17	0	0	0
18	19	1	0
19	9	0	0
20	10	0	0
21	19	1	0
Total	1,317	41	15

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in Figure 4-3. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, the land-based fecal coliform deposited by livestock while grazing.

Figure 4-3: Livestock Contribution to Birch Creek Watershed



Based on the inventory of livestock in the Birch Creek watershed, it was determined that beef cattle are the predominant type of livestock in the watershed. The inventory also indicated that there are no dairy cattle, poultry operations, goats, sheep, or swine in the watershed, and that the livestock do not spend any significant time in confinement.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on the livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spent in the stream was presented in Chapter 3.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix B.

4.7.4 Land Application of Manure

In the Birch Creek watershed, no dairy farms exist, and no reported manure storage facilities are present in the watershed. Land application of manure was not considered in the development of the Birch Creek TMDL.

4.7.5 Land Application of Biosolids

Although there is no sewage treatment plant located in the Birch Creek watershed, biosolids from the Danville Sewage Treatment plant and the Chatham Sewage Treatment plant are applied in the form of liquid or solid. The number of fields biosolids were applied to in Pittsylvania and Halifax Counties was presented in Chapter 3. Because there was no available information on whether these fields were located within the Birch Creek watershed, for TMDL development it was assumed that 50 percent of the biosolids were applied in the Birch Creek watershed. After examining biosolids data obtained from the Department of Health, it was estimated that an average of 3,000 dry tons were applied in Pittsylvania and Halifax Counties. Since it was assumed that 50 percent of this load was applied to fields in the Birch Creek watershed, 1,500 dry tons were incorporated into the model. The fecal coliform load from biosolids was distributed between cropland and pastureland.

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on the amount of time each type of wildlife spent on land and in the stream. Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the Birch Creek watershed. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed. Fecal coliform loading from wildlife is presented in Appendix B.

4.7.7 Pets

For the Birch Creek TMDL, pet fecal coliform loading was considered a land-based load that is primarily deposited on the residential areas in the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Birch Creek watershed. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in-storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

In the Birch Creek TMDL, no in-storage die-off was included in the model since there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure that model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to an observed dataset, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

The HSPF model was set up and calibrated based on the Falling River flow data and watershed characteristics, because there were no available stream flow data for Birch Creek. Falling River is located in Campbell and Appomattox counties. Birch Creek and Falling River are hydrologically similar, as was determined by analyzing land use conditions, drainage areas, slopes, and soil types within these two watersheds.

4.9.1.1 Paired Watershed Approach

Since stream flow monitoring data were not available in the Birch Creek watershed, the paired watershed approach was used in the set-up and calibration of the HSPF model. The basis of this approach is to develop the model for a hydrologically similar watershed where data are available, then to transfer the calibrated model to the watershed with the insufficient data. Criteria used to evaluate similarities in the hydrologic characteristics of these watersheds included watershed physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use/land cover) and mean annual precipitation.

Five streams with sufficient hydrologic data were identified for potential use as the paired watershed to Birch Creek. These included Totopotomoy Creek (USGS1673550), Fine Creek (USGS2036500), North Meherrin River (USGS2051000), Allen Creek (USGS2079640) and Falling River (USGS2064000). It was determined that Falling River would be used in this paired watershed approach. Birch Creek and Falling River are located approximately 21 miles from each other. Similarities between these watersheds are discussed below. A map depicting the locations of these watersheds is presented later in this chapter, in Figure 4-5.

The first step in the paired watershed approach is to examine the hydrologic similarity between the Falling River and Birch Creek watersheds. Land uses were divided into five categories: forested, agricultural, urban, water/wetlands, and other land uses. Table 4-5 shows these categories and the land use distribution in each category for the two watersheds. Non-urban areas, which include forested and agricultural lands, account for 95.4% of the Falling River watershed and 95.3% of the Birch Creek watershed. This indicates that land use in the Falling River watershed is representative of land use in the Birch Creek watershed.

Table 4-5: Summary of Land Use Distributions for Birch Creek and Falling River

Category	Land Use	% of Total Watershed	
		Birch Creek	Falling River
Forest	Deciduous Forest	38.5	40.7
	Evergreen Forest	16.9	11.6
	Mixed Forest	15.0	14.8
	Total Forested Land Uses	**70.4**	**67.1**
Agricultural	Pasture/Hay	18.8	25.4
	Row Crops	6.1	2.9
	Total Agricultural Land Uses	**24.9**	**28.3**
Urban	Low Intensity Residential	0.1	0.8
	Commercial/Industrial/Transportation	0.0	0.2
	Total Urban Land Uses	**0.1**	**1.0**
Water/Wetlands	Open Water	0.5	0.6
	Woody Wetlands	2.0	0.7
	Emergent Herbaceous Wetlands	0.2	0.1
	Total Water/Wetland Land Uses	**2.7**	**1.4**
Other	Transitional	2.0	2.3
	Total Other Land Uses	**2.0**	**2.3**

In addition to land use, the soil distribution in the watersheds was analyzed. Table 4-6 shows the soil types and distribution in each watershed. The soils series present in both the Falling River and Birch Creek watersheds consist of well-drained soils. Based on the hydrologic soil group classifications, the soil series present in the two watersheds predominantly range from “B” to “C”. Small areas in the Birch Creek and Falling River watersheds may have soils designated as hydrologic group “D”.

Table 4-6: Soil Distribution in Falling River and Birch Creek

Soil Id	Soil Name	Hydrologic Group	Percent of Watershed	
			Falling River	Birch Creek
VA014	Nanson-Manteo-Goldston	C/D	8.3	0
VA019	Cecil-Madison-Enon	B/C	26.8	91.0
VA029	Iredell-Pacolet-Poindexter	C/D/B	0.7	8.6
VA030	Appling-Wedowee-Louisburg	B	13.2	0
VA031	Cullen-Wilkes	C	15.7	0
VA033	Turbeville-Dogue-Edgehill	B/C	0	0.4
VA042	Creedmoor-Mayodan-Pinkston	B/C	7.6	0
VA045	Georgeville-Nason-Lignum	B	27.7	0

Additional watershed characteristics were also compared, including the drainage area, main channel slope, main channel length, and mean basin elevation of Falling River and Birch Creek. These data, presented in Table 4-7, also indicate that the physical characteristics of these two watersheds are similar.

Table 4-7: Comparison of Falling River and Birch Creek Watershed Characteristics

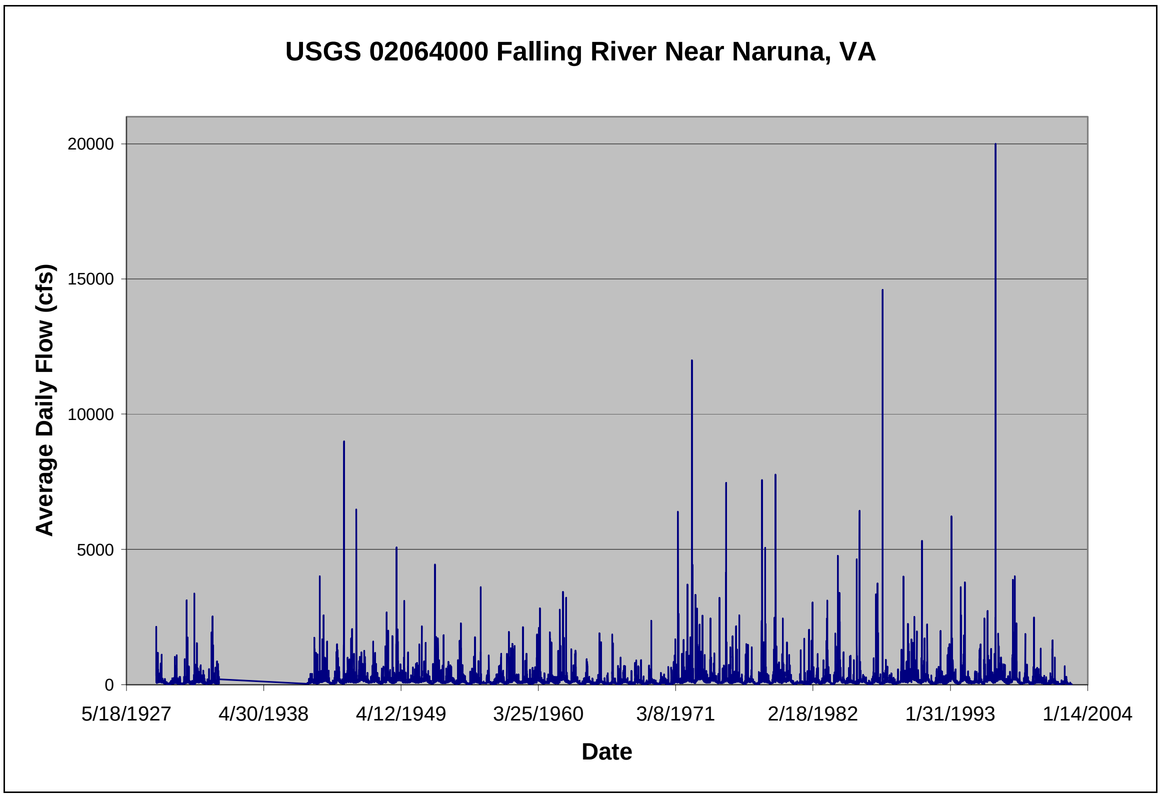
Watershed	Drainage Area (square miles)	Main Channel Slope (feet/mile)	Main Channel Length (mile)	Mean Basin Elevation (feet)
Falling River	236.2	14	34.2	879.3
Birch Creek	63.1	19.2	18.3	558

Based on land use data, soil distributions, and physical watershed characteristics, the Falling River watershed was determined to be hydrologically similar to the Birch Creek watershed. Therefore, Falling River, for which there were sufficient data, was used as a surrogate for setting up and calibrating the HSPF model. The model was then transferred to Birch Creek and used in the TMDL development.

4.9.1.2 Stream Flow Data

The Falling River watershed was chosen as a surrogate for calibration of the Birch Creek hydrologic model because there are no available stream flow data for Birch Creek, and the Falling River watershed in hydrologically similar to the Birch Creek watershed. Stream flow data for the Falling River watershed was available from USGS station #2064000, near Naruna. These data were used in TMDL development. The Falling River stream flow station has a period of record from 1929 to 2003. The drainage area above the station is approximately 173 square miles. Average flow data for the period of 1990 to 2002 were retrieved, and are plotted in Figure 4-4. Average flows of Falling River ranged from 1 to 20,000 cfs, with a mean flow of 153.44 cfs.

Figure 4-4: Daily Mean Flow (cfs) at USGS Gauging Station 2064000

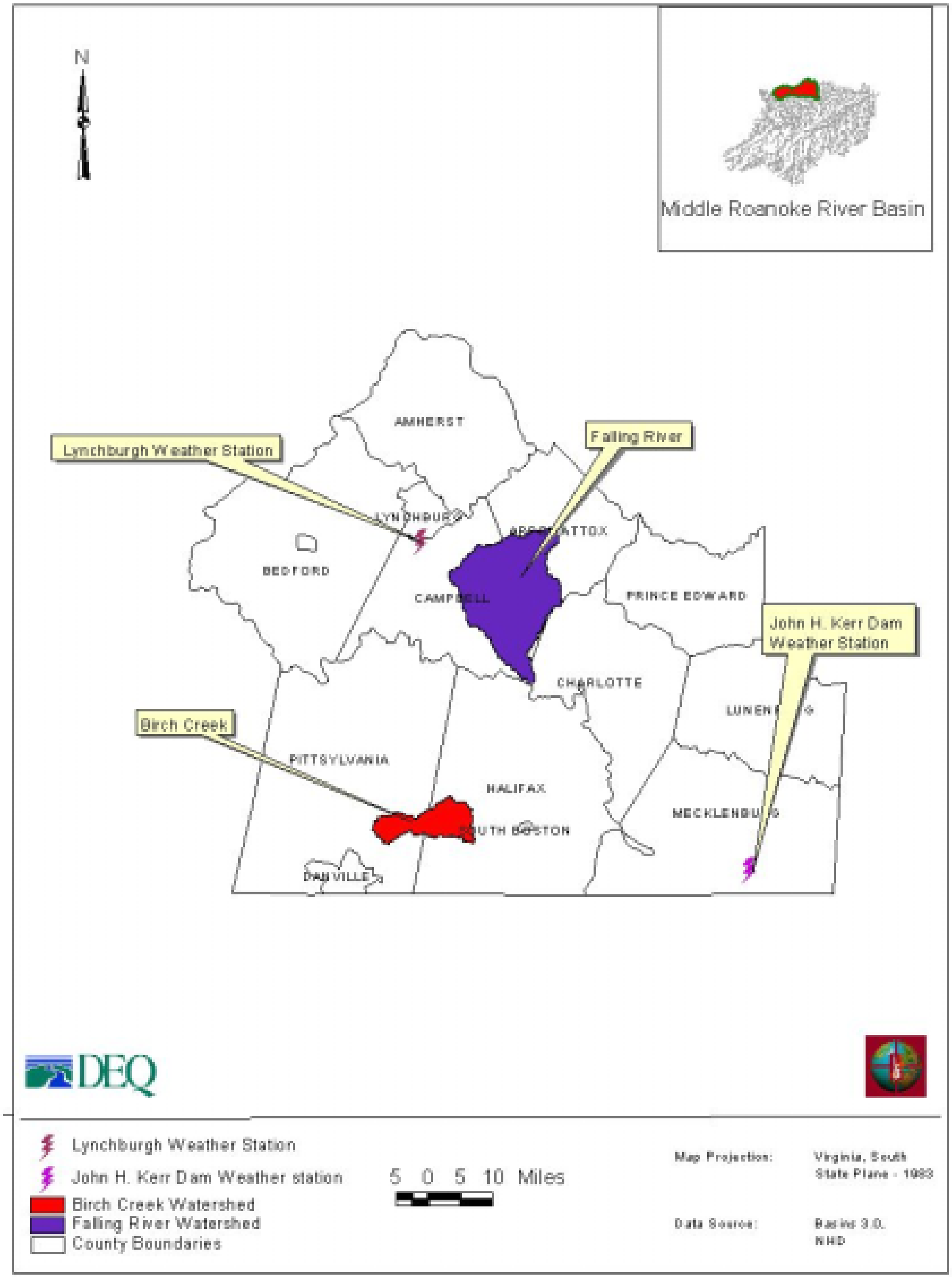


A 4-year period (1997-2000) was selected as the calibration period for the Falling River hydrologic model.

4.9.1.3 Rainfall and Climate Data

Weather data for the Lynchburg, VA WSO Airport and the John H. Kerr dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Lynchburg airport recorded data from 1952 to 2001, and the John H. Kerr dam recorded data from 1948 to the present. For this TMDL, the recorded data at Lynchburg and the Kerr dam were combined based on their proximity to the Falling River watershed, which was used as the paired watershed to Birch Creek. The combined rainfall record consisted of 75 percent Lynchburg weather data and 25 percent of the weather data obtained from the John H. Kerr dam. Figure 4-5 depicts the location of the weather stations.

Figure 4-5: Location of Rainfall Stations



4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the Falling River watershed. After each iteration of the model, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Falling River model was calibrated for January 1997 to December 1998. Calibration results are presented in Table 4-8, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in Table 4-9. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-10. The model results and the observed daily average flow at the Falling River station are plotted in Figure 4-6.

Table 4-8 Falling River Model Calibration Results

Category	Simulated	Observed
Total annual runoff, in inches	33.60	33.08
Total of highest 10% flows, in inches	15.02	13.75
Total of lowest 50% flows, in inches	5.19	5.48
Total storm volume, in inches	5.55	4.39
Average of storm peaks, in cfs	756.45	570.53
Baseflow recession rate	0.99	0.96
Summer flow volume, in inches	4.75	4.17
Winter flow volume, in inches	11.81	12.46
Summer storm volume, in inches	1.02	0.85

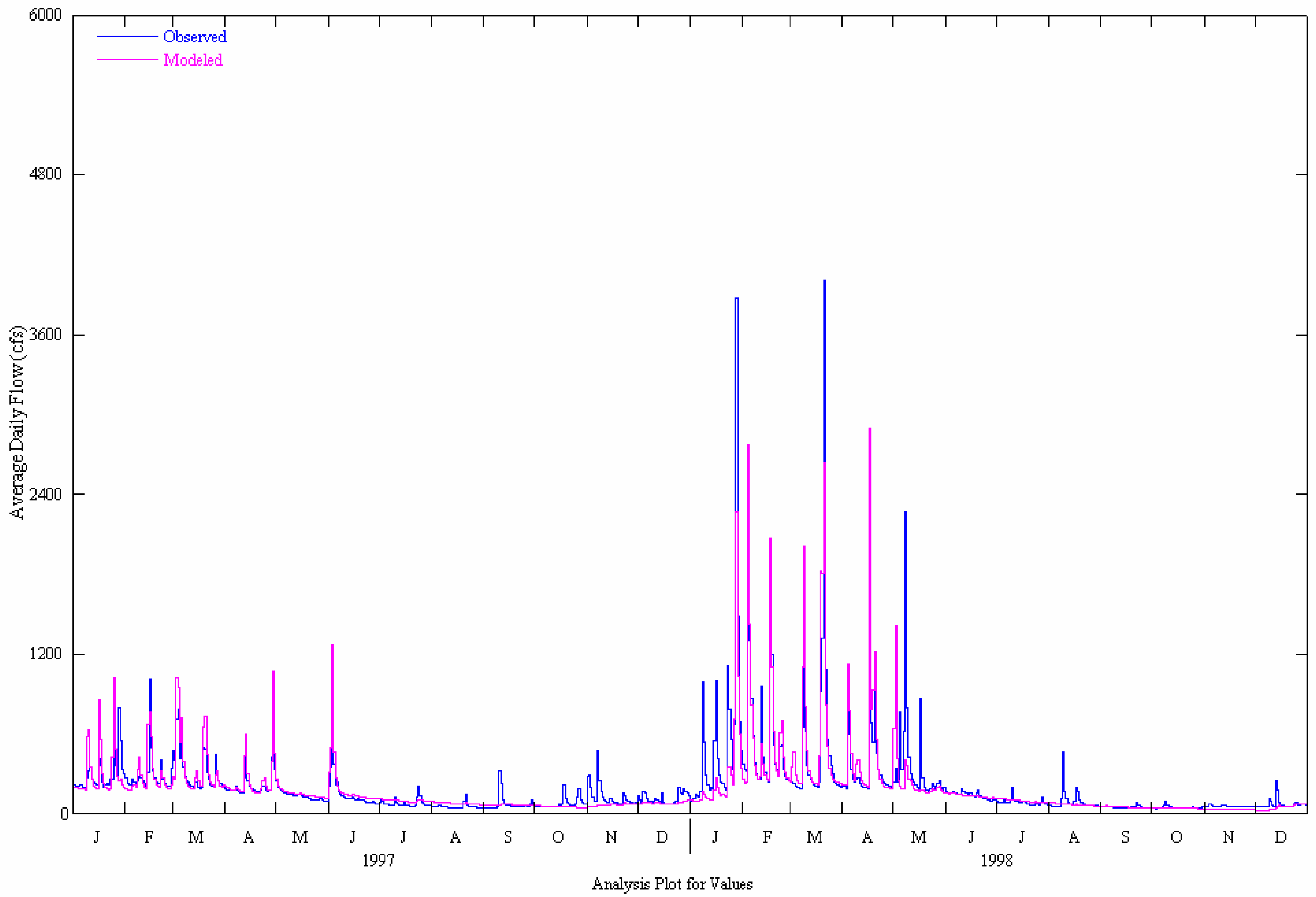
Table 4-9: Falling River Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	1.6	± 10.000
Error in low flow recession	-3.2	± 15.000
Error in 50% lowest flows	-5.4	± 10.000
Error in 10% highest flows	9.2	± 10.000
Error in storm volumes	32.6	± 10.000
Seasonal volume error	19.2	± 10.000
Summer storm volume error	-6.7	± 10.000

Table 4-10: Falling River Simulation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1997	1.57	2.25	9.80	11.5	16.5	72.0
1998	4.25	3.99	9.80	23.6	22.1	54.3
Average	**2.91**	**3.12**	**9.80**	**17.5**	**19.3**	**63.1**

Figure 4-6: Falling River HSPF Model Hydrologic Calibration Results



4.9.3 Model Hydrologic Validation Results

The period from January 1996 to December 1996 was used to validate the HSPF model. The validation results are presented in Figure 4-7 and the summary statistics from HSPEXP are presented in Table 4-11 and Table 4-12. The error statistics indicate that the validation results were within the recommended ranges in HSPEXP. Comparisons between simulated and observed values for summer storm volume were skewed by Hurricane Fran, which occurred from August 23rd to September 6th in 1996. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-13.

Table 4-11: Falling River Model Validation Results

Category	Simulated	Observed
Total annual runoff, in inches	18.30	20.21
Total of lowest 50% flows, in inches	4.87	5.34
Total of highest 10% flows, in inches	6.33	6.68
Total storm volume, in inches	0.95	1.07
Average of storm peaks, in cfs	400.46	439.78
Base flow recession rate	0.98	0.96
Summer flow volume, in inches	2.11	2.84
Winter flow volume, in inches	7.23	7.96
Summer storm volume, in inches	N/A[1]	N/A

[1] Due to the hurricane.

Table 4-12: Falling River Model Validation Error Statistics

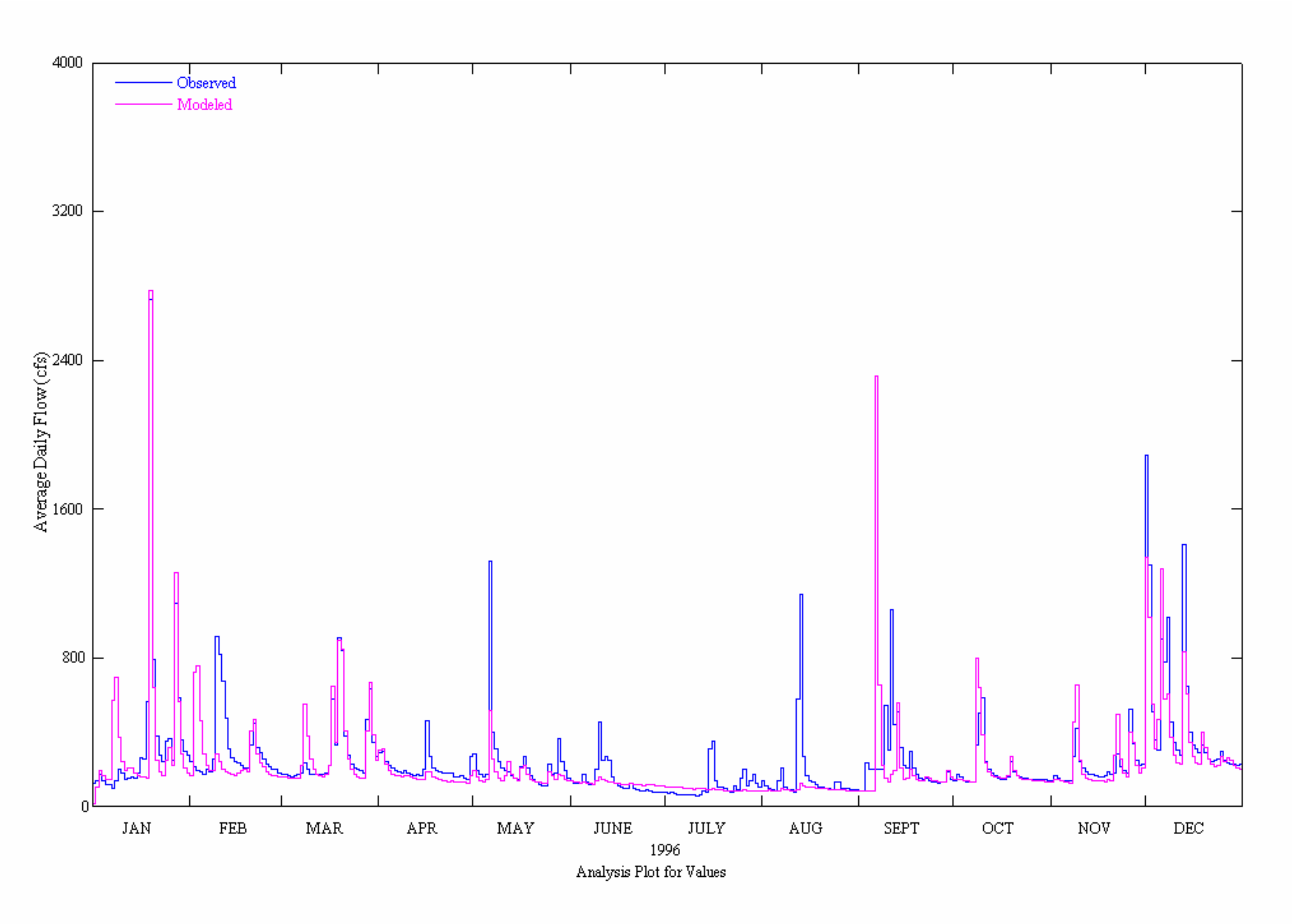
Category	Current	Criteria
Error in total volume	1.60	±10%
Error in low flow recession	0.03	±15%
Error in 50% lowest flows	-5.40	±10%
Error in 10% highest flows	9.20	±10%
Error in storm volumes	44.20	±10%
Seasonal volume error	19.20	±10%
Summer storm volume error	NA[1]	±10%

[1] Due to the hurricane

Table 4-13: Falling River Validation Water Budget

Water Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1996	3.26	3.16	11.7	18.0	17.4	64.6

Figure 4-7: Falling River - HSPF Model Hydrologic Validation Results



There is a good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. The model results closely match the observed flows during low flow conditions, base flow recession and storm peaks. The final parameter values of the calibrated model are listed in Table 4-14.

Table 4-14: Falling River Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Falling River
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	0.95	0-1
LZSN	Lower zone nominal soils moisture	inch	3	8	2	15	1-7
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.09-0.12
LSUR	Length of overland flow	Ft	200	500	100	700	250-300
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.0949
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0.1
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.0989-0.99
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.1
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.02
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0

Parameter	Definition	Units	Typical		Possible		Falling River
			Min	Max	Min	Max	
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	0.1
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.05	2	1.1
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	0.65
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.5
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	0.1
RETSC	Retention storage capacity of the surface	inch					
ACQOP	Rate of accumulation of constituent	#/ac day					5.99E+6-2.42E+11
SQOLIM	Maximum accumulation of constituent	#					1.08E+7 – 2.91E+11
WSQOP	Wash-off rate	Inch/hour					0.45 – 0.80
IOQC	Constituent concentration in interflow	#/CF					1416
AOQC	Constituent concentration in active groundwater	#/CF					283
KS	Weighing factor for hydraulic routing						0.5
FSTDEC	First order decay rate of the constituent	1/day					1.152
THFST	Temperature correction coefficient for FSTDEC	none					1.07

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up build-up, wash-off, and kinetic rates for fecal coliform that best describe the fecal coliform sources and environmental conditions within the watershed. It is an iterative process in which the model results are compared to available in-stream fecal coliform data, and model parameters are adjusted until there is an acceptable agreement between observed and simulated in-stream concentrations and fecal coliform build-up and wash-off rates are within acceptable ranges.

The available in-stream water quality data plays a major factor in determining the calibration and validation periods for the model. In Chapter 3, the in-stream monitoring stations were listed and the sampling events conducted on Birch Creek were summarized and presented. Station 4-ABIR001.00 is the most downstream station, and was sampled a total of 39 times from 1993-2001. Stations 4-ABIR004.22, 4-ABIR011.55, and 4-ABIR014.28 are located upstream of station 4-ABIR001.00; however these stations were only sampled a total of 12 times each in the time period of 2002-2003. Because station 4-ABIR001.00 is the most downstream station and possessed the most water quality data, collected over the longest time period, it was the station selected for model calibration.

Water quality data for station 4-ABIR001.00 was retrieved from STORET and DEQ, and were evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period of January 1995 to December 1996 was used for water quality calibration of the model, and the time period of January 1998 to December 2000 was used for model validation.

It is important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. Model-simulated fecal coliform concentrations represent the average daily values. Model-simulated and observed fecal coliform concentrations are plotted and presented in Figure 4-8 and Figure 4-9. The goodness of fit for the water quality calibration was evaluated visually. Analysis of model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. Table 4-15 shows the observed and simulated geometric mean fecal coliform concentration over the simulation period. Table 4-16 shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-15: Observed and Simulated Geometric Mean Fecal Coliform Concentration over the Simulation Period.

Segment	Watershed	Geometric Mean (cfu/100ml)	
		Observed	Simulated
21	Birch Creek	479	224.19

Table 4-16: Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard

Segment	Watershed	Rate of Exceedance	
		Observed	Simulated
21	Birch Creek	0.38	0.39

Figure 4-8: Water Quality Calibration

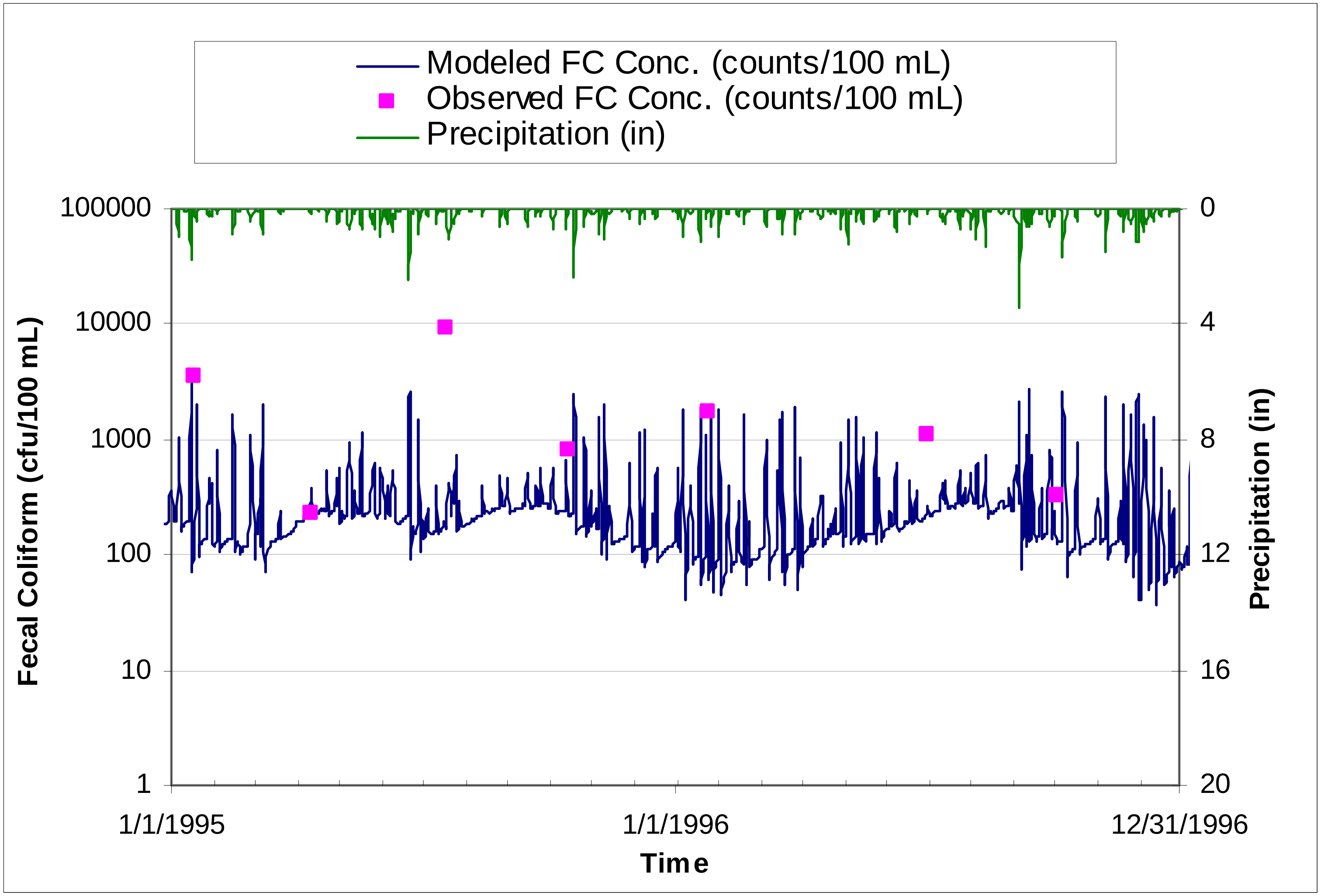
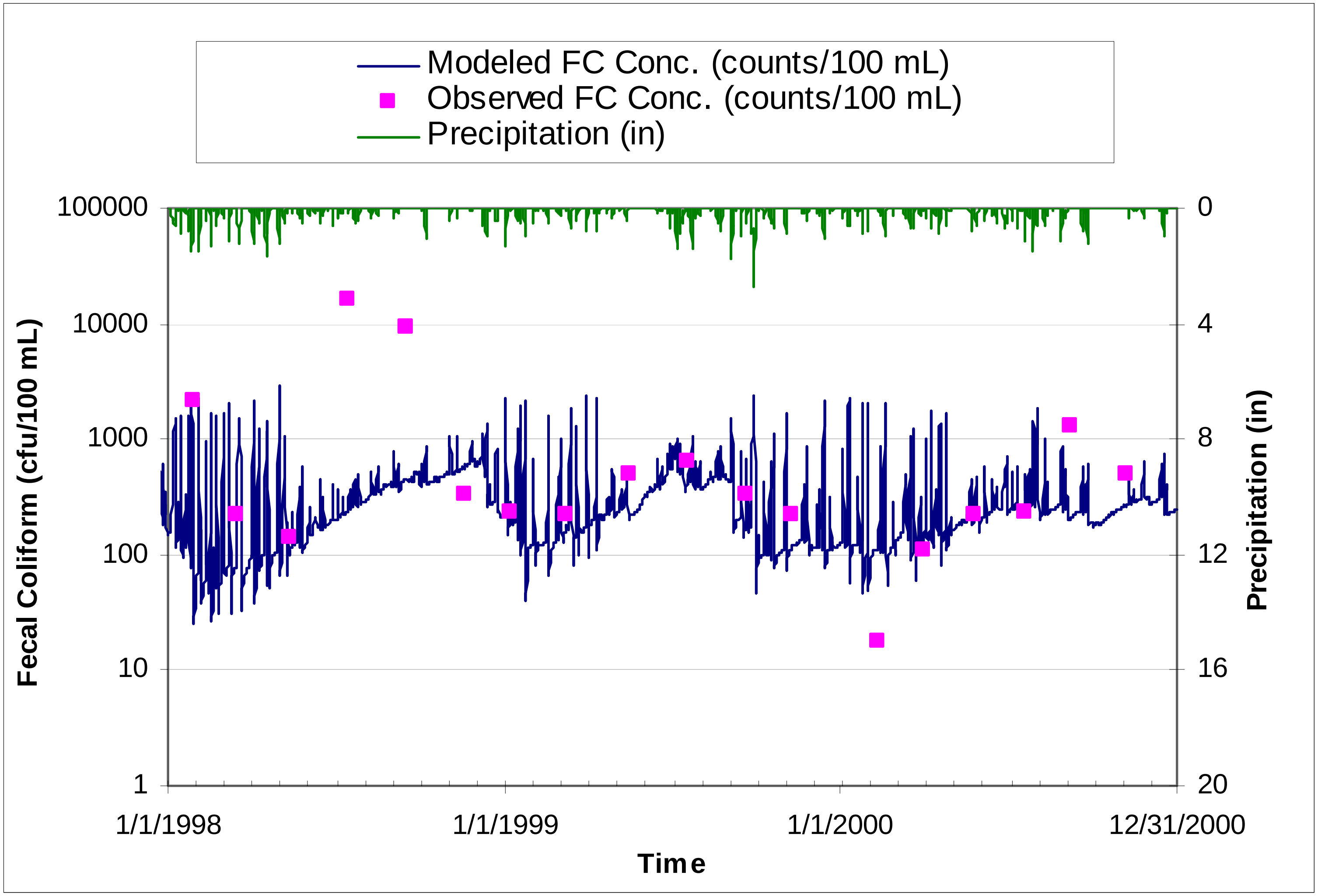


Figure 4-9: Water Quality Validation



4.10 Existing Bacteria Loading

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2000. Figure 4-10 shows the 30-day geometric mean fecal coliform concentration in Birch Creek. Figure 4-11 shows the instantaneous fecal coliform concentration in Birch Creek. These figures illustrate that the 200 cfu/100 ml geometric mean standard and the 400 cfu/100 ml instantaneous standards for fecal coliform were exceeded for the most part during this time period.

Figure 4-10: Geometric Mean Existing Conditions in Birch Creek

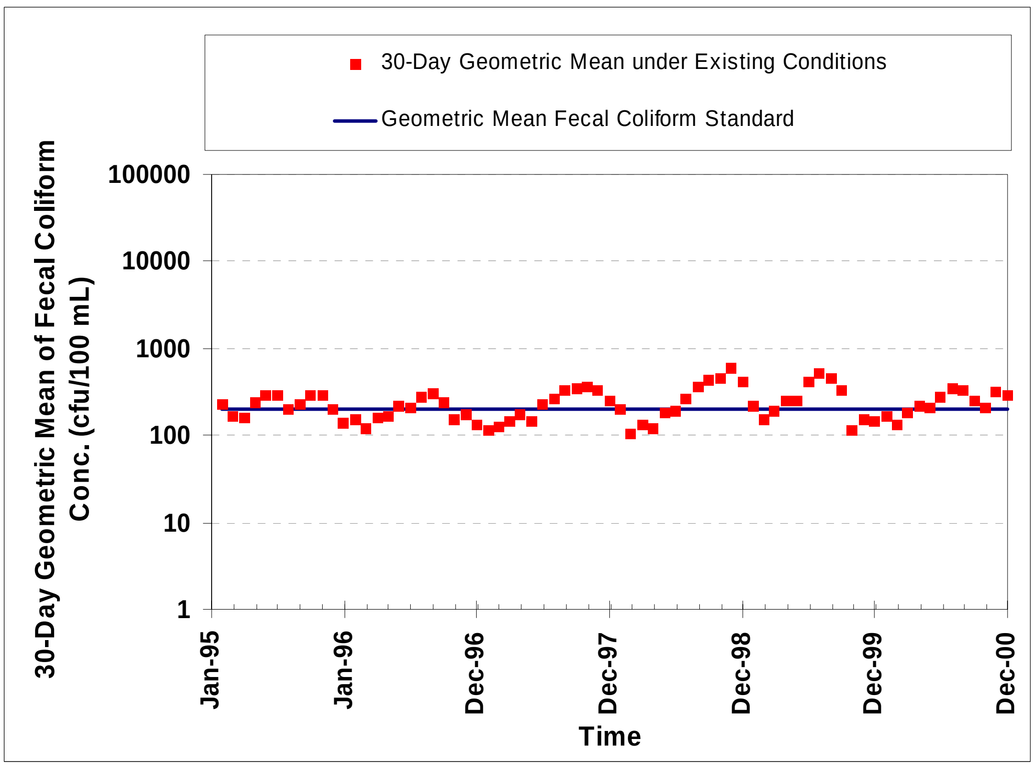
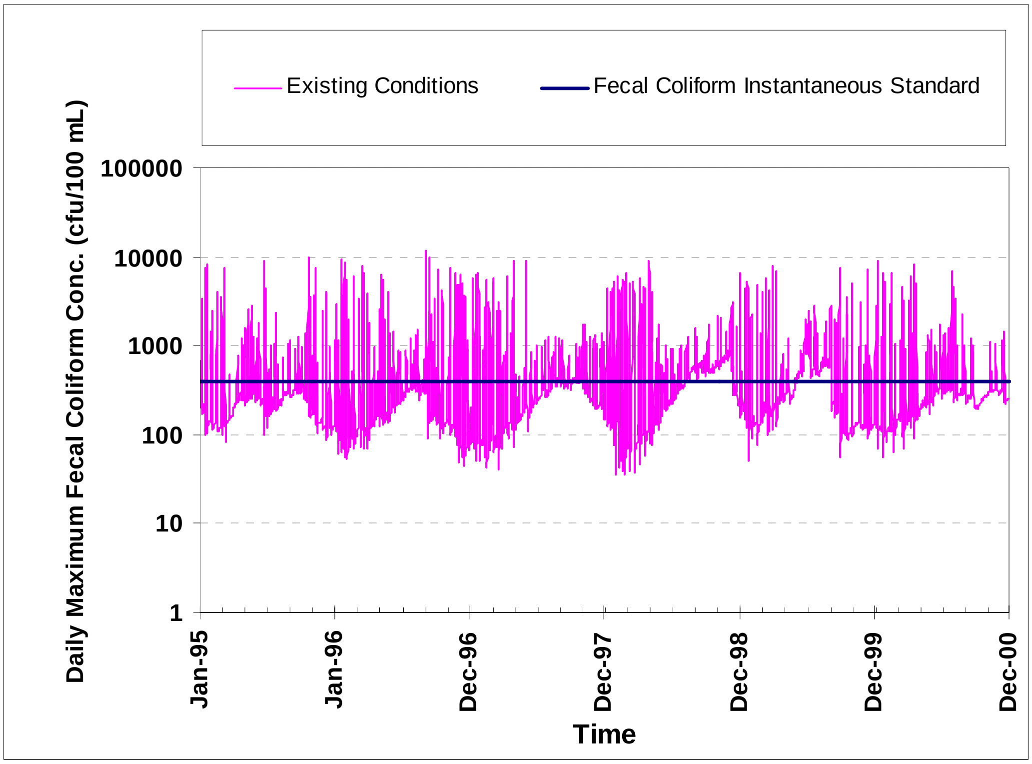


Figure 4-11: Instantaneous Existing Conditions in Birch Creek



Distribution of the existing fecal coliform load by source is presented in Table 4-17. The corresponding E. coli loading is presented in Table 4-18. E. coli concentrations were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below.

$$E.\ coli\ concentration\ (cfu/100\ ml) = 2^{-0.0172} \times (FC\ concentration\ (cfu/100ml))^{0.91905}$$

Tables 4-17 and 4-18 show that loading from the urban areas and pasturelands are the predominant sources of bacteria in the Birch Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from cattle and wildlife will dominate even though their loading is relatively small.

Table 4-17: Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent
Forest	1.40E+13	0.6%
Cropland	8.31E+11	0.0%
Pasture	1.32E+15	51.9%
Low Residential	1.10E+15	43.4%
Commercial/Industrial	7.72E+09	0.0%
Water/Wetland	1.16E+10	0.0%
Other	0.00E+00	0.0%
Failed Septic	5.12E+10	0.0%
Cattle direct	7.19E+13	2.8%
Wildlife	3.30E+13	1.3%
Point Source	0	0.0%
Total	**2.54E+15**	**100%**

Table 4-18: E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent
Forest	1.20E+12	0.8
Cropland	8.91E+10	0.1
Pasture	7.77E+13	50.8
Low Residential	6.60E+13	43.1
Commercial/Industrial	1.21E+09	0.0
Water/Wetland	1.75E+09	0.0
Other	0.00E+00	0.0
Failed Septic	6.87E+09	0.0
Cattle direct	5.37E+12	3.5
Wildlife	2.62E+12	1.7
Point Source	0	0.0
Total	**1.53E+14**	**100%**

5.0 Allocation

For the Birch Creek bacteria TMDL, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal coliform geometric mean standard of 200 cfu/100 ml and the instantaneous fecal coliform standard of 400 cfu/100 ml with 0% exceedance. In terms of E. coli, this will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the bacteria loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation, and provides insight and direction in developing the TMDL allocation and implementation. Based on the sensitivity analysis, several allocation scenarios were developed; these are presented in the next section. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for E. coli is shown. The results of the sensitivity analysis are presented in Appendix D.

5.3 Allocation Scenario Development

Allocation scenarios that would reduce the existing bacteria load to meet water quality standards were simulated using the HSPF model.

5.3.1 Wasteload Allocation

There are no permitted facilities discharging in the Birch Creek watershed (see Chapter 3). Therefore, there was no wasteload allocated in the development of the Birch Creek TMDL.

5.3.2 Load Allocation

The reduction of loading from non-point sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario. The scenarios considered are presented in Table 5-1. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.

- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).

Table 5-1: Birch Creek Load Allocation Scenarios

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0					
1	100				
2	100	50			
3	100	100			
4	100	100	100	100	
5	100	100			50
6	100	100			75
7	100	100	98	98	69
8	100	100	97.5	97.5	65
9	100	100	100	100	47

Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the Birch Creek HSPF model for the hydrologic period of January 1995 to December 2000. The estimated load reductions resulting from these allocation scenarios are presented in terms of E. coli in Table 5-2. This table indicates the percentage of days the 126 cfu/100ml E. coli geometric mean water quality standard and the 235 cfu/100ml E. coli instantaneous water quality standard were violated under each scenario. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 13 percent violation

of the E. coli geometric mean standard, and a 52 percent violation of the E. coli instantaneous standard.

3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 6 percent violation of the E. coli geometric mean standard, and a 37 percent violation of the E. coli instantaneous standard.

4. No violation of either E. coli standard occurred under Scenario 7, in which there was complete elimination of the human sources (failed septic systems and straight pipes) and livestock direct deposition, and 98 percent reduction of non-point sources coming from both agricultural and urban lands, and a 69 percent reduction of direct loading by wildlife.

5. Scenario 8 did not result in violations of the E. coli geometric mean standard; however the instantaneous E. coli standard of 235 cfu/100ml was not met. The instantaneous standard was also not met under Scenario 5 and Scenario 6. Scenario 9 did not violate the geometric mean or instantaneous E. coli standards, but required a 100 reduction of non-point sources and 47 percent reduction in direct loading by wildlife.

Therefore, Scenario 7 was chosen as the final TMDL load allocation scenario, because this scenario met both the instantaneous and geometric mean E. coli standards, and did not require 100 percent reduction of non-point sources.

Table 5-2: Birch Creek Load Reduction under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0						61	100
1	100					61	100
2	100	50				39	100
3	100	100				13	52
4	100	100	100	100		6	37
5	100	100			50	0	39
6	100	100			75	0	39
7	100	100	98	98	69	0	0
8	100	100	97.5	97.5	65	0	3
9	100	100	100	100	47	0	0

5.4 TMDL Summary

Based on the load allocation scenario analysis above, the TMDL allocation plan (Scenario 7) that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml requires:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 69 percent reduction of the direct instream loading from wildlife.

Table 5-3 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix C.

Table 5-3: Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads		Percent Reduction (%)
	Existing	Allocation	
Forest	1.20E+12	1.20E+12	0
Low Density Residential	6.60E+13	1.81E+12	97
Pasture	7.77E+13	2.13E+12	97
Cropland	8.91E+10	2.45E+09	97
Commercial/Industrial/Transportation	1.21E+09	1.21E+09	0
Failed Septic/straight Pipes load	6.87E+09	0.00E+00	100
Direct deposition from cattle	5.37E+12	0.00E+00	100
Direct deposition from wildlife	2.62E+12	8.94E+11	66[1]
Point Sources	0.00E+00	0.00E+00	0
Total loads /Overall reduction	**1.53E+14**	**6.04E+12**	**96**

1: Translation from fecal coliform to E. coli standards changed percent reduction by wildlife from 69 to 66 percent.

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in Figure 5-1 and Figure 5-2. Figure 5-1 shows the 30-day geometric mean E. coli loading after applying allocation Scenario 7, as well as geometric mean loading under existing conditions. Figure 5-2 shows the instantaneous E. coli loading after applying allocation Scenario 7, as well as instantaneous loading under existing conditions. Allocation Scenario 7 results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for E. coli. A summary of the TMDL allocation plan loads for Birch Creek is presented in Table 5-4.

Table 5-4: Birch Creek TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
0	6.04E+12	Implicit	6.04E+12

Figure 5-1: Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 7

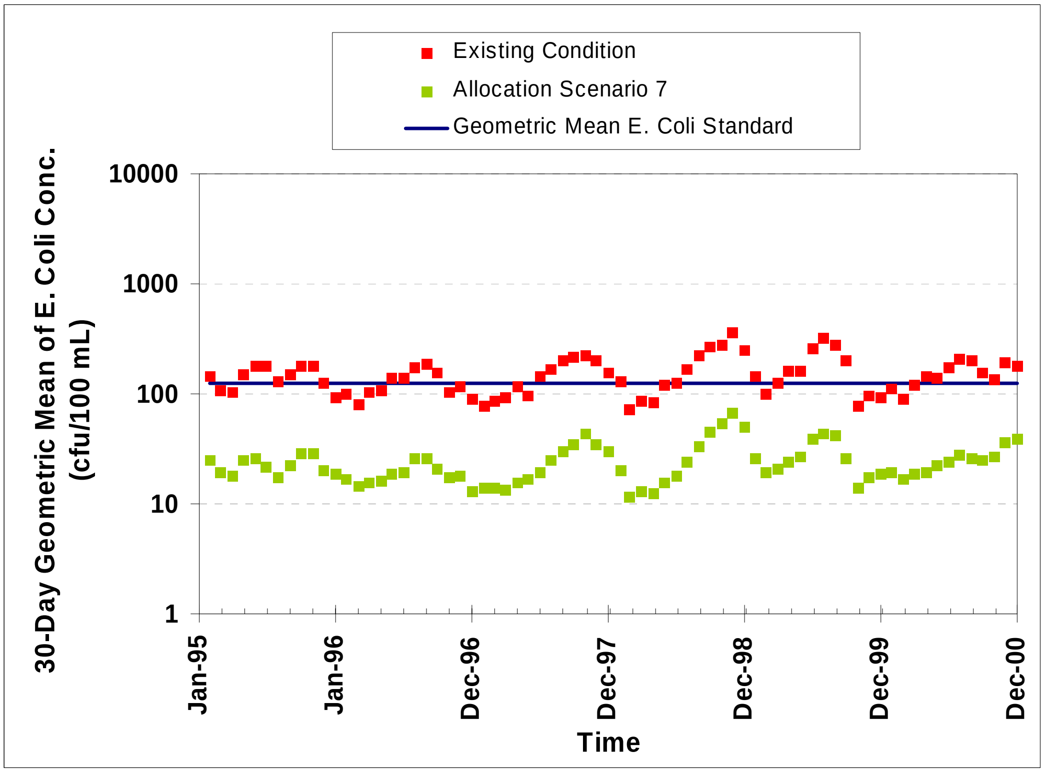
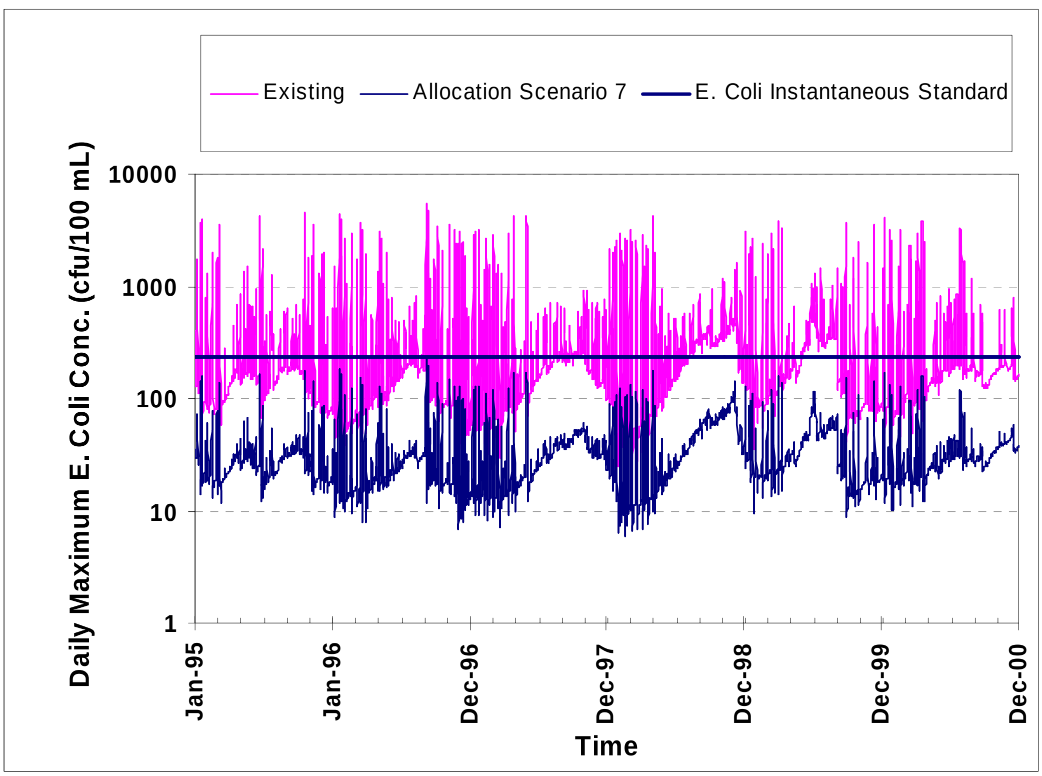


Figure 5-2: Instantaneous E. coli Loadings under Existing Conditions and Allocation Scenario 7



6.0 TMDL Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on Birch Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring.

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling.

3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements.

4. It helps ensure that the most cost effective practices are implemented first.

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios. It was estimated for modeling purposes that there are 15 straight pipes in the watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Birch Creek and its tributaries.

Three scenarios are presented in Table 6-1. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Birch Creek Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml
1	100	100	98	98	38	10%
2	100	100	70	70	0	43%
3	100	100	98	98	0	37%

Under Scenario 1, the E. coli instantaneous standard of 235 cfu/100ml was violated 10 percent of the time. This condition requires the following reductions:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.

- 38 percent reduction of the direct instream loading from wildlife.

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Birch Creek watershed.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

VADEQ will continue monitoring 4-ABIR001.00, 4-ABIR004.22, 4-ABIR011.55, and 4-ABIR014.28 in accordance with its ambient monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia’s 1997 Water Quality Monitoring Information and Restoration Act (the “Act”) directs the State Water Control Board to “develop and implement a plan to achieve fully supporting status for impaired waters” (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 “Guidance for Water Quality-Based Decisions: The TMDL Process.” The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.4.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Non-point Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. As is the case for Birch Creek, these streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new “secondary contact” category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for “secondary contact recreation” which means “a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)”. These new criteria became effective February 2004 and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 6.1 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

7.0 Public Participation

The development of the Birch Creek TMDL would not have been possible without public participation. Three public meetings we held in the Birch Creek watershed, the following is a summary of the meeting objectives and attendance.

TAC Meeting. The TAC meeting was held in the Town of Halifax on April 10, 2003 to discuss the process for TMDL development, present the listed segment of Birch Creek and present the data that caused the segment to be on the 303(d) list, identify review the data and information needed in the TMDL development, and officially request data and information. Thirteen people representing the various State and local government agencies attended this meeting. Copies of the presentation materials were available for public distribution. The meeting participants were contacted by DEQ via Email and phone.

Public Meeting No. 1. The first public meeting was held in the Town of Halifax on October 23, 2003 to present the following:

- listed segment of Birch Creek,
- the data that caused the segment to be on the 303(d) list,
- review the TMDL process;
- the livestock, wildlife, and pet inventories;
- the fecal coliform sources assessment
- the calculation used to estimate the total available fecal coliform load;
- explain the assumptions used in the calculations; and present the HSPF model.

Nine people attended the meeting. Copies of the presentation were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received.

Public Meeting No. 2. The second public meeting was held in the Town of Halifax on February 23, 2004 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Ten people attended the meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

References

American Society of Agricultural Engineers, (ASAE) 1998. ASAE standards, 45th edition.

Metcalf and Eddy. 1991. Wastewater Engineering: Treatment, Disposal, Reuse. 3rd Ed. McGraw-Hill, Inc, New York.

U.S. Environmental Protection Agency (EPA). 1985. Rates, Constants, and Kinetics formulations in Surface Water Quality Modeling. Athens, GA

U.S. Environmental Protection Agency (EPA). 2001. “Overview or Current Total Maximum Daily Load (TMDL) Program and Regulations.” Available at <http://www.epa.gov/owow/tmdl/overviewfs.html> Website visited October 1, 2003.

U.S. Environmental Protection Agency (EPA). 2001. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), Version 3 Washington, DC.

U.S. Environmental Protection Agency (EPA). 2001b. Protocols for developing Pathogen TMDLs

U.S. Census Bureau. 1990. 1990 U.S. Census Data for Halifax County and Pittsylvania County, Virginia. Available at <http://venus.census.gov/cdrom /lookup> Website visited December 20, 2003.

U.S. Census Bureau. 2000. 2000 State and County Quick Facts, Halifax County and Pittsylvania County, Virginia. Available at http://quickfacts.census.gov/qfd/states/51/51121.html> Website visited December 20, 2003.

U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS). 2000. STATSGO Soils Browser CD-ROM Version 1.0. February 2000.

Virginia. *Virginia Administrative Code.* 1997. VAC 25-260-5 et seq. Water Quality Standards. Available at < http://www.deq.state.va.us/wqs/wqs97.pdf> Website Visited August 29, 2003.

Virginia Department of Environmental Quality (DEQ). 2001a. “Total Maximum Daily Loads, Background-Legal and Regulatory Framework.” Available at <http://www.deq.state.va.us/tmdl/backgr.html> Website visited October 1, 2003.

Virginia Department of Environmental Quality (DEQ). 2001b. Proposal *for Bacteria, Recreational Uses, and Ammonia.* Available at <http://www.deq.state.va.us/wqs/bacteria.pdf> Website visited October 2, 2003.

Virginia Department of Environmental Quality (DEQ). 2001. "Total Maximum Daily Loads." Available at <http://www.deq.state.va.us/tmdl> Website visited October 1, 2003.

Virginia Department of Environmental Quality (DEQ). 2000. *Total Maximum Daily Load Program, A Ten Year Implementation Plan-Report to the Governor, House Committees, and Senate Committees, November 1, 2000.* Available at <http://www.deq.state.va.us/tmdl/reports/hb30.pdf> Website visited October 1, 2003.

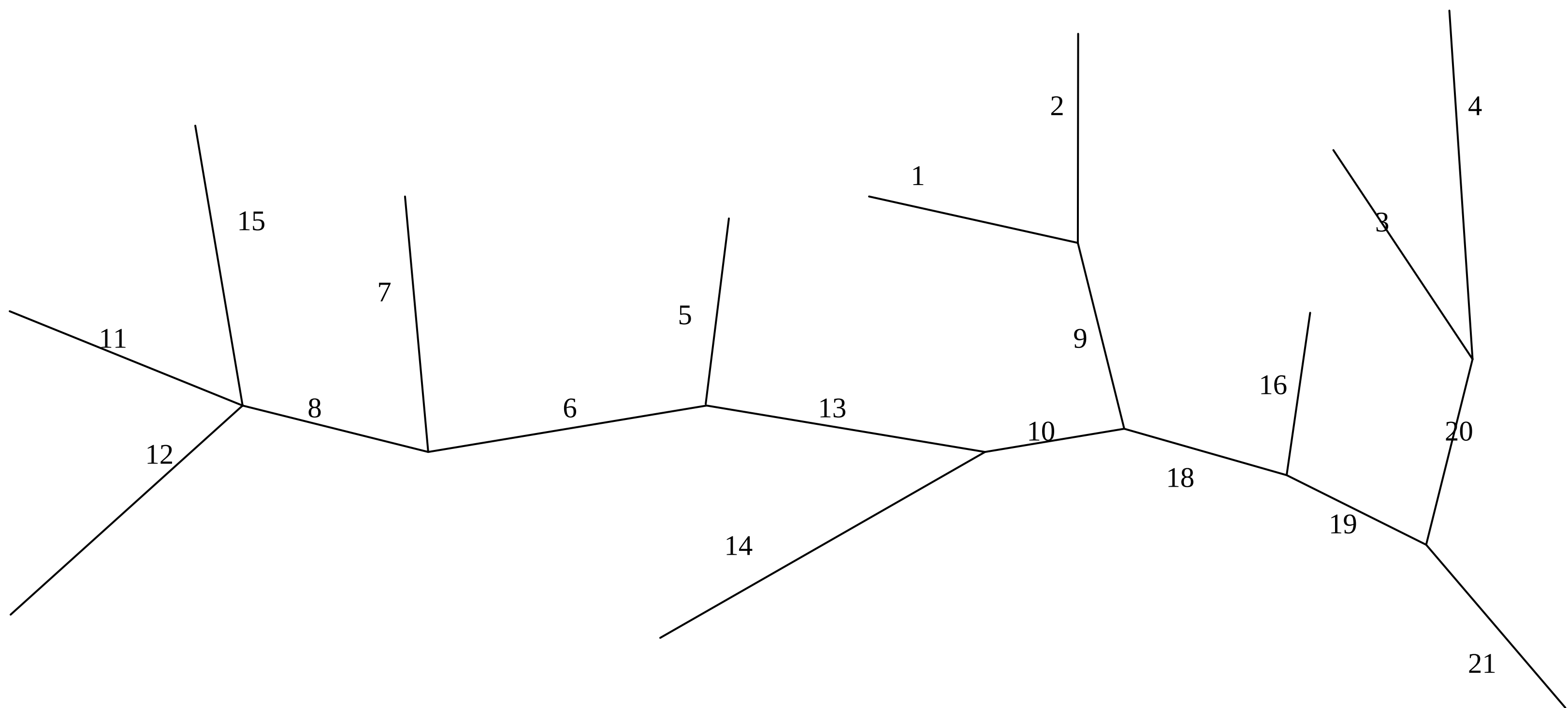
Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation (DEQ and DCR). 2000. Fecal Coliform TMDL Development for Middle Blackwater River, Virginia. Prepared by MapTech Inc., December 27, 2000.

Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation (DEQ and DCR). 2000. Fecal Coliform TMDL Development for Cedar, Hall, Byers, and Hutton Creeks, Virginia. Prepared by CH2Mhill, October 2000.

Virginia Department of Environmental Quality (DEQ). 2002. 2002 *Water Quality Assessment Report, Part III Surface Water Monitoring.* Available at <http://www.deq.state.va.us/wqa/305b.html> Website visited October 2, 2003.

Appendix A

Model Representation of Stream Reach Networks



Model Representation of Birch Creek Model Stream Network

Appendix B

Monthly Fecal Coliform Build-up Rates

Table B-1: Birch Creek Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.43E+07	2.43E+07	2.43E+07	2.43E+07	2.43E+07	2.43E+07
Cropland	2.00E+07	1.00E+10	1.00E+10	2.00E+10	7.00E+09	2.00E+10
Pasture	1.00E+09	2.00E+09	2.00E+09	4.00E+09	2.00E+09	4.00E+09
Low Residential	2.42E+11	2.42E+11	2.42E+11	2.42E+11	2.42E+11	2.42E+11
Comm/Ind/Trnsprt	5.99E+06	5.99E+06	5.99E+06	5.99E+06	5.99E+06	5.99E+06

Table B-2: Birch Creek Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.43E+07	2.43E+07	2.43E+07	2.43E+07	2.43E+07	2.43E+07
Cropland	7.00E+09	2.00E+10	1.00E+10	2.00E+10	1.00E+10	2.00E+07
Pasture	3.00E+09	4.00E+09	3.00E+09	4.00E+09	3.00E+09	1.00E+09
Low Residential	2.42E+11	2.42E+11	2.42E+11	2.42E+11	2.42E+11	2.42E+11
Comm/Ind/Trnsprt	5.99E+06	5.99E+06	5.99E+06	5.99E+06	5.99E+06	5.99E+06

Table B-3 Birch Creek Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	5.71E+11	2.80E+12	1.76E+09
2	1.03E+12	2.53E+12	1.59E+09
3	1.71E+12	2.80E+12	1.76E+09
4	1.66E+12	2.71E+12	1.70E+09
5	2.28E+12	2.80E+12	1.76E+09
6	2.21E+12	2.71E+12	1.70E+09
7	2.28E+12	2.80E+12	1.76E+09
8	1.71E+12	2.80E+12	1.76E+09
9	1.10E+12	2.71E+12	1.70E+09
10	1.14E+12	2.80E+12	1.76E+09
11	5.52E+11	2.71E+12	1.70E+09
12	5.71E+11	2.80E+12	1.76E+09

Appendix C

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table C-1 Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland
1	2.89E+12	1.67E+11	2.72E+14	1.94E+14	1.24E+09	1.02E+09
2	1.88E+12	1.13E+11	1.68E+14	1.17E+14	8.72E+08	1.26E+09
3	2.60E+12	1.55E+11	2.30E+14	1.91E+14	1.26E+09	1.40E+09
4	1.85E+12	1.05E+11	1.71E+14	1.45E+14	9.74E+08	1.23E+09
5	6.10E+11	3.53E+10	6.05E+13	5.00E+13	4.27E+08	1.08E+09
6	8.35E+11	5.00E+10	8.19E+13	1.27E+14	7.70E+08	9.05E+08
7	7.82E+10	9.08E+09	1.39E+13	2.19E+13	2.23E+08	8.06E+08
8	7.57E+10	7.46E+09	1.09E+13	1.63E+13	1.83E+08	7.22E+08
9	1.15E+12	6.73E+10	1.06E+14	1.05E+14	6.74E+08	7.22E+08
10	4.21E+11	2.73E+10	4.06E+13	3.79E+13	3.15E+08	8.03E+08
11	6.86E+11	4.37E+10	7.17E+13	3.87E+13	3.17E+08	7.43E+08
12	9.61E+11	5.16E+10	9.12E+13	5.90E+13	4.61E+08	8.83E+08

Table C-2 Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland
1	2.89E+12	3.33E+09	5.44E+12	3.89E+12	1.24E+09	1.02E+09
2	1.88E+12	2.27E+09	3.37E+12	2.34E+12	8.72E+08	1.26E+09
3	2.60E+12	3.09E+09	4.59E+12	3.82E+12	1.26E+09	1.40E+09
4	1.85E+12	2.10E+09	3.41E+12	2.89E+12	9.74E+08	1.23E+09
5	6.10E+11	7.06E+08	1.21E+12	1.00E+12	4.27E+08	1.08E+09
6	8.35E+11	1.00E+09	1.64E+12	2.53E+12	7.70E+08	9.05E+08
7	7.82E+10	1.82E+08	2.77E+11	4.38E+11	2.23E+08	8.06E+08
8	7.57E+10	1.49E+08	2.18E+11	3.27E+11	1.83E+08	7.22E+08
9	1.15E+12	1.35E+09	2.12E+12	2.10E+12	6.74E+08	7.22E+08
10	4.21E+11	5.46E+08	8.13E+11	7.58E+11	3.15E+08	8.03E+08
11	6.86E+11	8.74E+08	1.43E+12	7.74E+11	3.17E+08	7.43E+08
12	9.61E+11	1.03E+09	1.82E+12	1.18E+12	4.61E+08	8.83E+08

Appendix D

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Birch Creek flows through a rural setting. Potential sources of fecal coliform include nonpoint (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model input parameters on the fecal coliform annual loading and the fecal coliform concentration in Birch Creek. For the hydrologic period, January 1998 to December 1998, the model was run under various land based and the direct deposition loading scenarios which include the following:

- 10 percent increase in land based loads
- 10 percent decrease in land based loads
- 100 percent increase in land based loads
- 100 percent decrease in land based loads
- 10 percent increase in direct deposition loads
- 10 percent decrease in direct deposition loads
- 100 percent increase in direct deposition loads
- 100 percent decrease in direct deposition loads

The results of the sensitivity analysis are presented in Figures D-1, D-2, and D-3. Based on these figures it can be seen that a reduction of the direct deposition load is more effective in reducing the instream fecal coliform concentration under low flow condition and consequently meeting the water quality targets for Birch Creek.

Figure D-1. Effects of source reduction on the annual fecal coliform load

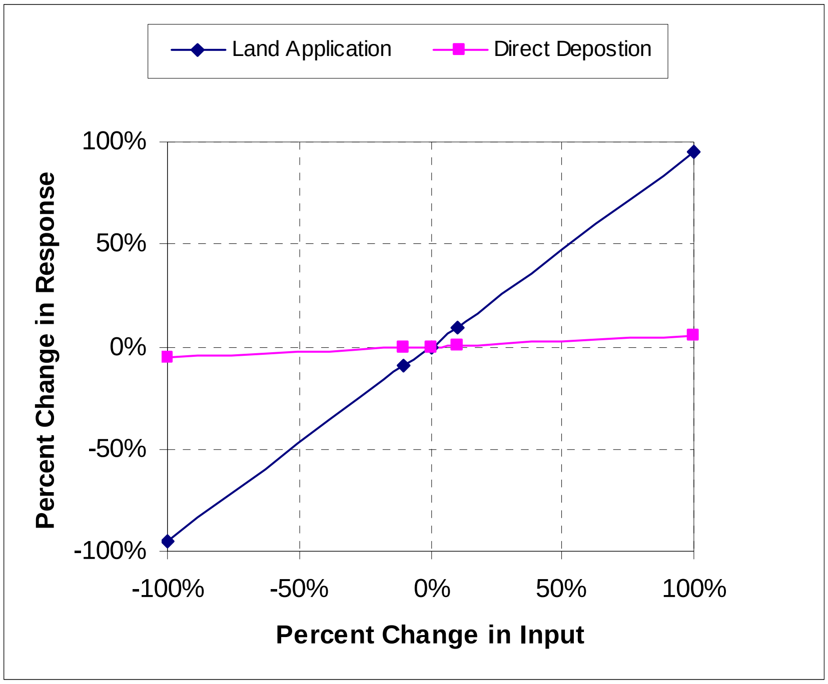


Figure D-2. Effect of changes in land based loads on monthly maximum geometric mean fecal coliform concentrations.

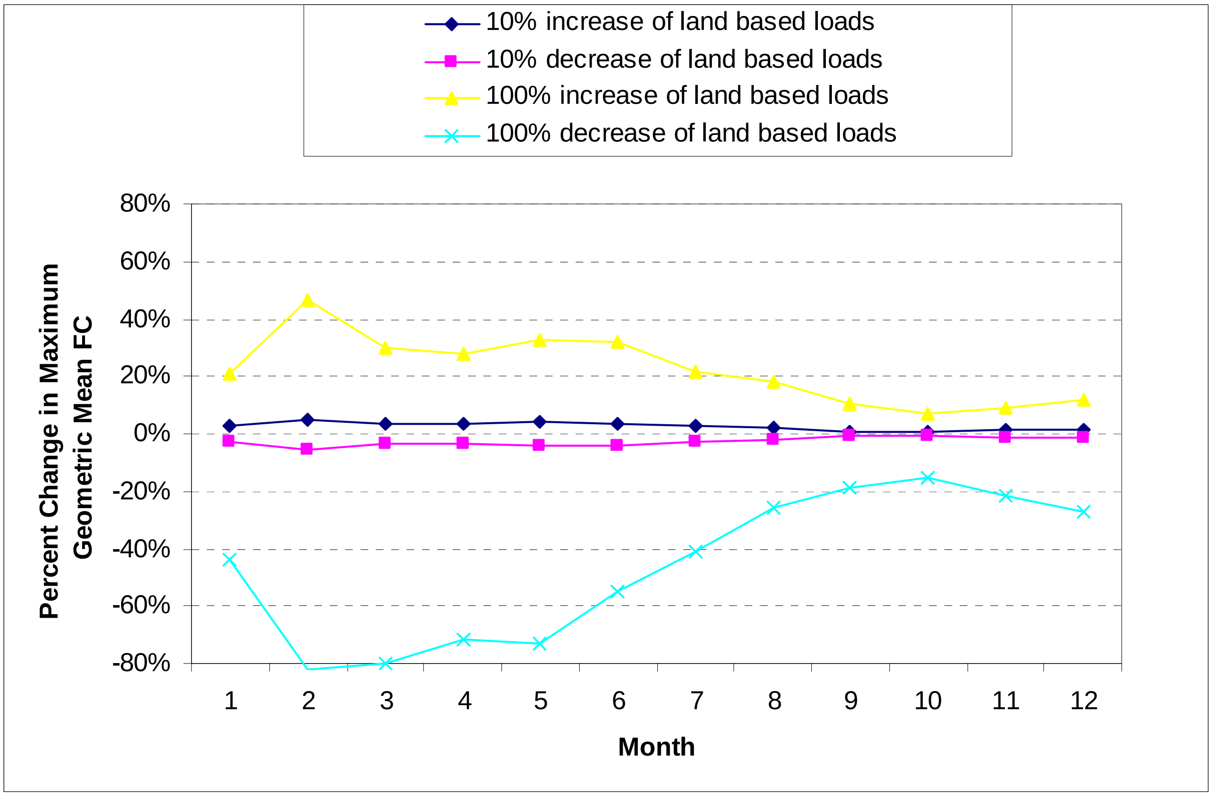


Figure D-3. Effect of changes in direct loads on monthly maximum geometric mean fecal coliform concentrations.